XPANSTRUS

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E. K. Lawrence Jr.

EXPANDED METAL CO. of PHILADELPHIA, Gen. Agts.

CAMDEN, N. J,

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A HAND-BOOK OF DESIGN CONTAINING TABLES, STANDARDS AND USEFUL INFORMATION APPERTAINING TO

The "Xpantrus" System

of Reinforced Concrete

THE CONSOLIDATED EXPANDED METAL COMPANIES

PITTSBURGH, PENNSYLVANIA

No. 4766

It will be noted that this handbook is of the loose leaf form.

It is our intention to forward to you, from time to time, for insertion, additions such as costs of installations, data compiled from tests, and illustrations of construction methods.

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THE CONSOLIDATED EXPANDED METAL COMPANIES
PITTSBURGH, PA.

PREFACE

REINFORCED CONCRETE has now reached a point in its development where the exacting demands of engineers necessitate a shop-fabricated unit. This can only be effected by a complete standardization, not unlike that encountered in rolled steel sections which alone made possible its universal application. To make such a form of reinforcement practical, it is necessary to develop a complete unit system and so design it that it may be feasible in manufacture, advantageous to the designer, and applicable to the erector. The complete standardization of a reinforced concrete system is a laborious task necessitating an immense amount of the most painstaking work, and an intimate knowledge of modern requirements.

¶ The object of this hand-book is to bring together information and data relative to the "Xpantrus" bar and accompanying system in such form as to be of most service to engineers and architects. Probably the most difficult task encountered in the compilation of this hand-book was the selection of the formulae and theory of design. Not a little disagreement even among the "authorities" is found. The formulae and theory of design adopted conform to that recommended by the report of a committee of four leading technical societies composed of prominent engineers.

¶ The tables compiled are necessarily conservative, yet we hope are not so one-sided as to prove unserviceable to engineers and contractors at large. We believe that they will be of inestimable help to users of "Xpantrus" bars. The most careful scrutiny was given in their compilation to insure accuracy, and within the limits of a common slide rule are without error. The form of presenting them, while not commonly encountered in trade hand-books, will be readily recognized by engineers and architects to be of a character calculated to eliminate a fruitful source of error. Preliminary to the tables has been added a brief discussion of the formulae and theory which lead to the more approximate ones used in subsequent calculations. The two objects aimed at were simplicity and conformity to the above mentioned report. We are indebted to Professors Turneaure and Maurer of the University of Wisconsin for the use of figures 2 and 3 which are taken from their book on "Principles of Reinforced Concrete Construction."

REINFORCED CONCRETE CONSTRUCTION.

Foreword

In a period scarcely spanning twenty years REINFORCED CONCRETE CONSTRUCTION bears witness to a growth from a comparatively new business to an immense industry. Indeed many of the men who helped to develop it in its infancy are still in harness designing and directing important work. Nor should the remarkable growth of this industry be surprising when one considers the sterling qualities for which concrete-steel construction stands. Briefly stated these qualities are: Strength combined with rigidity, permanency combined with low cost, and the fact that it is fireproof in its very nature, necessitating no additional material for this essential qualification.

Since the introduction of reinforced concrete, the distribution of the steel in the concrete has been the great object of investigation. Systems innumerable have been advanced and examples of successful construction in numerous bridges, buildings, etc., are used by their promoters to argue their relative advantages. Early analysis and investigation had pointed to the great possibilities of the steel imbedded in the concrete. The function of the steel being opposite to that of the concrete, it remained for engineers to ascertain, by theoretical analysis as well as by laboratory experiments, the distribution of the tensile stresses in a concrete beam in order to locate the position of the steel. As might have been expected from the great importance of the problem, the full fire of engineering argument and debate was directed towards its solution and even yet the fight is by no means over; probably never will be. At present the debate centers about the merits and demerits of the details of the various systems. The inevitable results of discussion and of experiment must be, and have been, the survival of the fittest, until now the peculiar advantages and disadvantages of any system are readily discernible.

Essential Requirements

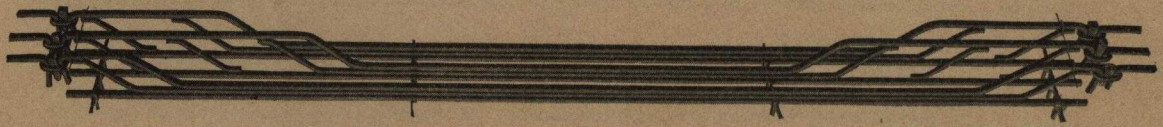
All systems aim, most of them more or less crudely, to fulfill the recognized requirements and to develop in full the possibilities of the steel. In order to appreciate the great importance to be attached to the difference in concrete-steel systems, it is first necessary to note and enumerate the great general requirements.

(1) **PRACTICABILITY.** Any system to be of the most value to the trade, as well as to the engineering profession, must be so adapted that the theoretical distribution of the steel in the concrete in practice will be perfect while incurring the minimum expense for installing. It must be easy of inspection and so adaptable that all of the steel for an entire floor or large area may be inspected in position and approved before the placing of any concrete. This is a very important requirement and *SHOULD BE EMBODIED IN EVERY SPECIFICATION.*

Concrete-steel construction has in the past been severely and justly criticized in this respect. This uncertainty is entirely eliminated in the "Xpantrus" System presented and described in this handbook.

(2) EFFICIENT SHEAR MEMBERS. The so-called shear members or stirrups should be placed at an angle of 45° and be rigidly anchored *BOTH AT THE TOP AND AT THE BOTTOM OF THE BEAM*. This is in accordance with the best engineering practice. Its purpose is twofold: first, to insure the correct location and position of the shear member in the beam during the placing of the concrete; this being usually left to unskilled labor under irresponsible supervision. Secondly, it is necessary to develop the full strength of the shear member as the stresses developed in them are transmitted to them only by the gripping of the concrete. Shear members unanchored, or anchored at one end only, are invariably too short to develop their full strength previous to their slipping in the concrete. A shear member anchored at both ends as is the case with the "Xpantrus" Bar, insures full development of the value of the steel. Such a beam may be counted upon to develop at least twenty per cent. more strength than similar beams using only loose stirrups for web reinforcement. A contractor can readily see what this means in dollars and cents. The question of shear members is taken up more fully in a subsequent discussion on the shear members and the diagonal tension. It is referred to here owing to its importance in concrete reinforcement, and to point out that the loose rod method is inefficient and expensive.

(3) PROVISION FOR CONTINUITY. The reinforcement of the upper flange of a concrete beam at a support is an essential function of the steel and in accordance with the best recognized practice of the present day. This important function cannot be underestimated and forming, as it does, an essential part in the safety of the building requires the most careful attention of the field force and the inspectors. In the "Xpantrus" system the inspection is easy, the certainty of perfect continuity assured. In no other system is this as well taken care of.



"Xpantrus" System—Three bar unit frame.

THE "XPANTRUS" BAR.

Fulfills Exacting Requirements

In presenting the "Xpantrus" Bar to engineers, architects, and contractors, we desire to point out first that we do not advance any new theory, nor do we attempt to destroy any of the old ones. We desire merely to demonstrate a system which fulfills the most difficult and exacting requirements. The "Xpantrus" System stands out pre-eminently and alone for the two great qualities: THE ELIMINATION OF DOUBT and THE ONE HUNDRED PER CENT EFFICIENCY OF THE STEEL. In these two features this system outdistances all competitors.

It may safely be predicted that if reinforced concrete work will follow other lines of engineering endeavor and will hold its place as a sound and sane construction, all principles, systems, or members, whose usefulness cannot be definitely ascertained, or whose value cannot be mathematically investigated, or which is in any way uncertain in practical application, will be completely supplanted in time by such systems best fulfilling these requirements which are exacted in every other branch of engineering.

THE BAR.

The bar is rolled from a high grade of open hearth steel, essentially of the section shown in the cut, with varying cross-sections, namely, ½, ¾, 1, 1¼, 1½, 1¾ and 2 square inches. These full sections obtain in the middle third of the beam where it is needed. In the process of manufacture this bar is slit along the webs and expanded on the ends. The centre bar then becomes the shear member inclined at an angle of 45°. The top bar becomes the reinforcement for the upper flange of the beam. The lower bar is a sufficient reinforcement for the lower flange of the beam. The steel is thus economically distributed, placing it just where it is needed, in the right amount, and removing all unnecessary metal. The saving in steel is obvious even to the neophyte. To the initiated member of the trade it is at once a simple and easy solution to a difficult problem.

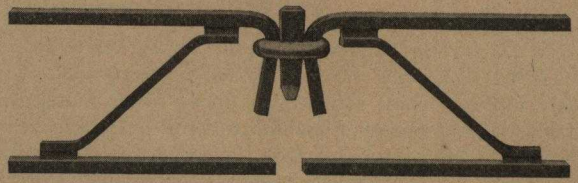
The height of the expanded bar at present may range from 4″ to 32″ and by special arrangement up to 36″. Standard heights, commonly called rises, may be found in tabulated form in subsequent tables.

The "Xpantrus" Bar is applicable chiefly to beams, girders and heavy slabs. For the lighter slab work, Expanded Metal mesh is unexcelled and we strongly urge its adoption in all such cases. The inquirer may readily find it fully described with tables for its use in the circulars of this company.

The Shear Member

The shear member in the "Xpantrus" Bar, as has already been pointed out, is firmly attached to the upper and lower flange bars, the web tie attaching it being sufficiently strong in shear to develop the full strength of the web member in tension, even causing the failure to occur in the shear bar rather than at the tie, this being in accordance with good engineering practice. All the steel in the beam is thus enabled to act as a unit with the concrete in forming a properly reinforced beam. The advantages thus offered have been already pointed out.

The shear members of the "Xpantrus" Bar lie in the same plane as the main tension members thus giving the maximum strength to the frame. Any reinforcing bars with shear members attached to the side of the main tension members are subject to the objection of eccentric loading in any construction. Such a detail would not be tolerated in the older industry of structural steel and should not be permitted in any conservative reinforced-concrete work.



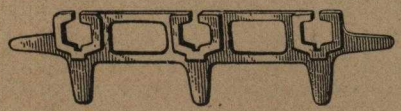
Method of providing for continuity over support. Note rigid tie of shear members—both top and bottom flanges.

The Upper Flange Bar

The Upper Flange Bar is bent into a hook form at the end, a link and wedge making the connection with the bar adjoining, thus cheaply and efficiently providing for the continuity of the beam. It thus ties together all the beams across a building, making it stiffer and stronger, the steel being continuous from one end to the other. Aside from the saving acquired, a still greater advantage is derived from this method of continuity, in that a perfect inspection is made possible before any concrete is placed, hence the certainty of the reinforcement. Conservative engineers will readily see the importance of this feature. Enterprising contractors will at once note the saving in labor and material and the elimination of doubt.

Combined Chair and Spacer

The wonderful adaptability of the bar is not completely grasped until the cast chairs and spacers accompanying the system are clearly comprehended. The bars entering into a beam are held in their theoretical position on the forms by resting on small cast malleable iron chairs at the lower flange bar and stiff wire spacers on the upper flange bar, these latter being intended merely to keep the expanded bar plumb and the proper distance from the edge. Architects will note at once the guarantee thus offered in fire protection from the assured amount of concrete below the bar and on the sides of the beam.



Combination chair and spacer—Three-bar unit frame.

Shipments

The bars constituting a unit frame, cast chairs, top wire spacers, and link and wedge for each beam are shipped wired together, tagged and knocked down, thus making it cheap to handle, easy to pile at the job, and simple to put in place. The architect or engineer may feel perfectly safe in believing that the distribution of the steel will be exactly as computed.

Economy of Installation

The contractor knows that the cost of handling, all else being equal, varies in direct proportion to the number of pieces to be handled. The "Xpantrus" Bars have the fewest pieces to be handled of any reinforced-concrete system in the market. It is therefore the cheapest bar in the market in this respect.

SPECIFICATIONS FOR STEEL WORK.

General

The steel shall be made by the Open Hearth process and shall conform to the Manufacturers Standard Specifications. All steel shall be rolled from new stock. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth, uniform and workmanlike finish.

All steel shall be free from paint, oil, grease or heavy rust.

All rods or bars must be straight along their full length when lying in the forms. They must be properly spaced and rigidly held in place by means of chairs, and spacers to prevent any possibility of misplacement during the pouring of the concrete. Full details of chairs and spacers must be submitted before any reinforcement will be considered.

All joists, beams and girders must be amply reinforced against diagonal tension. Shear members must be inclined at an angle of 45°. They shall be rigidly connected to the main tension member on the

lower portion of the beam. All shear members must extend well into the compression flange of the beam and be rigidly anchored there. No reinforcement will be considered that does not comply with this essential detail. No loose stirrups will under any circumstances be allowed.

All steel reinforcement must be so adaptable as to permit inspection by the architect of an entire floor or large area as the occasion may demand before the pouring of any concrete.

"Xpantrus" System

The reinforcing steel for all footings, girders, beams and heavy floor slabs, throughout where needed to be of the "Xpantrus" system.

Shop-made units of sufficient strength shall be selected to develop the full efficiency of the steel. The unit working strength for the steel shall not exceed 16,000 pounds per square inch. There shall be sufficient web reinforcement allowed so that the concrete will not be required to take more than 50 pounds per square inch in shear. This will in every case be taken care of by the selection of the proper "Xpantrus" bar. No loose stirrups will, under any circumstances, be allowed.

All bars, together with cast chairs, and top wire spacers shall be placed in strict accordance with plans and details. All adjoining beams and girders must be clamped together over the support with link and wedge in accordance with standard details. The whole shall be inspected by the architect before any concrete is placed. All forms shall be thoroughly cleaned prior to the placing of the reinforcing steel.

THE HIGH ELASTIC LIMIT AND THE DEFORMED BAR.

The High Elastic Limit

Many bars in the market are advocated by their promoters because of their high elastic limit, these bars being made of high carbon steel. We submit that instead of being any advantage, this is decidedly undesirable in ordinary building work and can be so clearly demonstrated that we can predict with certainty the passing of this quality of steel in concrete reinforcement. This would still be true if for no other reason than that medium steel runs in uniform quality, hence reliable, whereas the opposite may be said of high carbon steel, namely that it is difficult to obtain in uniform qualities, hence not adaptable to conservative construction. Until recently concrete-steel has been so new an industry, its possibilities so unexplored, its advocates so enthusiastic, that the ordinary conservatism of the engineering profession has in many cases been discarded. We share the enthusiasm of its warmest advocates as regards its future, but we believe it will have to be amenable to scientific principles and conservatism. In no other respect does this apply more than in the use of steel with enormous elastic limits. Indeed this class of material is prohibited to-day in all specifications of first-class reinforced concrete work. High carbon steel means brittleness

unless rigidly inspected. No specification is safe which permits a value for minimum elastic limit of 45,000 pounds per square inch in any hot finished bar, because this elastic limit can be created in only one way—the addition of carbon. The ultimate failure of a concrete beam reinforced with high carbon bars will be sudden and its resistance to shocks less than the resistance of a beam with low carbon steel for the reason that the resiliency of the milder steel is lacking in the former construction.

Even granting that a uniform steel could be procured with a high elastic limit, it can still be demonstrated that the high unit stresses in the steel cannot be attained in the reinforced concrete beam. The modulus of elasticity is the same for high carbon as for medium steel. This fact is apparently lost sight of by the advocates of the high carbon bar. This means that for equal loads, the elongation of the steel will be the same. The limit of the unit stress in the steel is *FIXED BY THE CONCRETE* which is required to elongate the same as the steel or else cracks will occur which is synonymous with failure. It is therefore necessary merely to ascertain that allowable stretch at which concrete will show injurious cracks to ascertain the allowable unit stress on the steel. Theoretically, cracks should appear at the ultimate tensile stress of concrete, which is very low, usually 200 pounds per square inch, and which corresponds to an allowable stress in the steel of between 3000 and 4000 pounds per square inch. It is a matter of common knowledge based on numerous experiments, and for reasons which cannot be gone into here, that noticeable cracks do not appear until long after this point is passed. It is, of course, impossible to state exactly at what unit stress in the steel the injurious cracks appear. The unanimous verdict of specifications governing all important reinforced concrete work, which may be accepted as the stand taken by conservative engineers is that the steel should not be stressed more than 16,000 pounds per square inch and in many cases less A high carbon brittle bar with high elastic limit therefore cannot possibly be of any use or take its place in sound and sane construction. The "Xpantrus" Bar is of medium open hearth steel which is easily obtained in uniform quality, and selected for the emphatic reasons above stated.

Deformed Bars

High carbon steel is invariably the quality selected to make the innumerable deformed bars with which the market is at present flooded. The claims for this form of bar are two-fold:—

1. To increase the grip of the concrete and thus utilize the high unit stresses of high carbon steel.

2. To provide a mechanical bond for the bar along its entire length and thus saving the expense of bending the bar which constitutes the common anchorage for plain rods or bars.

We submit first what has already been demonstrated, namely that high unit stresses cannot be obtained in a concrete beam and hence the same argument applies for this form of reinforcement as for high carbon

bars. Moreover deformed bars do not offer the economical or satisfactory bond between the concrete and the steel. The mechanical bond obtained is due primarily to the deformations which tend to resist the slipping through the concrete. While it is true that this offers a greater resistance to slippage than a plain rod or bar, nevertheless it creates a longitudinal shear along the rod, requiring more concrete between the rods, and hence the web must be made thicker. To do this more concrete is of course needed than would otherwise be required. These added stresses are a direct result of the deformations and while not amenable to mathematical computation their presence is generally recognized and should be provided against. Not infrequently designs are executed in which deformed bars are laid very close together. We maintain such designs are dangerous and should never be permitted.

Unquestionably the ideal bond is that in which the steel bar units are latticed, permitting them to be thoroughly enmeshed in the concrete. Such a bond is attained in a finished "Xpantrus" bar. No possibility of slippage is encountered. No uncertain shearing stresses are developed in the concrete.

It may be noted here that the universal practice in Europe where concrete-steel has been vigorously exploited, sanctions the usage of plain rods or bars. It is claimed by them that good labor is cheap there and the bending and correct placing can therefore be done economically. The "Xpantrus" Bar requires little labor in placing, a cheap quality may be used, and with ordinary supervision a perfect system of reinforcement is assured.

GENERAL THEORY AND DESIGN.

In selecting a basis for design of concrete-steel structures, the engineer, architect or contractor has in view two principal objects, (1) the safety of the building, (2) the economy of the construction. No formula, for beams of any material, yet devised is exact; hence the requirements that they should first, err on the side of safety, secondly, all other things being equal, the simplest is the most desirable. Reinforced concrete is a complex material and hair-splitting accuracy in design is neither possible nor necessary. While such beams can be subjected to rigorous mathematical investigation, the formulæ deduced are complex and unwieldy and the results attained, compared with those of the more simple formulæ hereinafter deduced and at present in common use, do not warrant the refinement.

The "Joint Committee"

In 1903 and 1904, in the interests of simplicity and uniformity, special committees were appointed by the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, and the Association of American Portland Cement Manufacturers to confer and unite in recommending necessary factors and formulæ required in the design of structures in which concrete-steel is used. This "Joint Committee" was organized and finally adopted

the following general assumptions as a basis for calculations relating to strength of structures. The formulæ and theory hereinafter presented are based on the assumptions recommended by this body of engineers. Where we have not given exactly the formulæ found in their report, it is because we have aimed at simplicity, believing the refinement attained in some cases is unnecessary in ordinary routine work. In every case the error will be found to be on the side of safety. Where exceptional cases of design occur, the designer should not hesitate to avail himself of more exact formulæ.

These assumptions are as follows:

(1) Calculations should be made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

(2) A plane section before bending remains plane after bending.

(3) The modulus of elasticity of concrete in compression, within the usual limits of working stresses, is constant. The distribution of compressive stresses in beams is therefore rectilinear.

(4) In calculating the moment of resistance of beams, the tensile stresses in the concrete shall be neglected.

(5) Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are therefore stressed in proportion to their moduli of elasticity.

(6) The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete may be taken at 15.

(7) Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

Afterwards the sixth assumption is modified by stating that a value of 8 to 12 for the ratio of the moduli corresponds more nearly to theoretical conditions and may well be used in deflection formulæ. In such cases the tensile strength of concrete should be taken into account.

These assumptions are made in the interest of simplicity and uniformity. Variations of exact conditions are taken into account in the selection of factors and unit stresses in the formulæ. Whatever error occurs is on the side of safety, hence they are conservative.

The design of concrete-steel buildings entails the design of simple and continuous rectangular and

T beams, slabs, columns and footings. These will now be briefly covered and the practical formulæ in every case submitted may be taken as good standard practice and conservative. For a complete discussion of them the reader is referred to the latest edition of "The Principles of Reinforced Concrete Construction" by Professors Turneaure and Maurer of the University of Wisconsin. The brief discussion given below is essential to the clear understanding of the formulæ and their application. It is inserted here, principally for any engineer unaccustomed to design concrete-steel who may wish to familiarize himself with the common formulæ, and their derivations, in use in conservative reinforced concrete work. Any reinforced concrete engineer will readily recognize them as the common ones adopted and used in conservative practical work. Other structures such as bridges, culverts, arches, sewers, bins, chimneys and innumerable other cases where concrete-steel is applicable are not covered here owing to limited space.

For the use of designers all the formulæ are summarized on page 41 and practical examples given from which the requisite steps for design of the simplest reinforced concrete members occurring in building work may be clearly grasped. Also subsequently are given complete tables applicable to the "Xpantrus" Bar covering all ordinary cases in simple and continuous beams. These tables have been carefully compiled by our engineering department and will be found to be of inestimable value to users of the "Xpantrus" Bar.

RECTANGULAR BEAMS.

The following notation is adopted from the standards of the "Joint Committee:"

f_s = tensile unit stress in steel.

f_c = compressive unit stress in concrete.

E_s = modulus of elasticity of steel.

E_c = modulus of elasticity of concrete.

$$n = \frac{E_s}{E_c}$$

M = Moment of Resistance or Bending Moment in general.

M_s = Moment of Resistance of Steel or that bending moment which is determined by the steel.

M_c = Moment of Resistance of Concrete or that bending moment which is determined by the concrete.

A = steel area.

b = breadth of beam.

d = depth of beam to center of steel.

k = ratio of depth of neutral axis to effective depth, d.

z = depth of resultant compression below top.

j = ratio of lever arm of resisting couple to depth, d.

$jd = d - z$ = arm of resisting couple.

$$p = \text{steel ratio} = \frac{A}{b\,d}$$

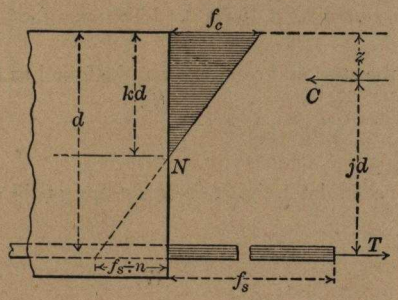


FIG. 1.

From mechanics we know that the total compression in the concrete must equal the total tension in the steel, hence we have, referring to figure 1.

$$\tfrac{1}{2} f_c\, b\, kd = f_s\, A$$

$$\frac{f_s}{f_c} = \frac{1}{2}\left(\frac{bd}{A}\right) k = \frac{k}{2p} \qquad (1)$$

From the mechanics of materials and assumption (2) we have

$$\frac{f_s}{f_c\, n} = \frac{d - kd}{kd} = \frac{1 - k}{k} \qquad (2)$$

Combining equations (1) and (2), eliminating the term $\frac{f_s}{f_c}$, and solving for k we have for the position of the neutral axis

$$k = \sqrt{2\, p\, n + (p\, n)^2} - p\, n \qquad (3)$$

From assumption (3) we have

$$z = \tfrac{1}{3}\, kd$$

hence, $jd = d - \tfrac{1}{3}\, kd$

or, $j = 1 - \tfrac{1}{3}\, k \qquad (4)$

For the unit stresses commonly used $f_s = 15{,}000$ to $16{,}000$ and $f_c = 600$ to 750, j may be taken at $\frac{7}{8}$ and k at $\frac{3}{8}$.

The moment of resistance of the steel and concrete may be found as follows:

$$M_s = jd\, f_s\, A \qquad (5)$$

or approximately

$$M_s = \tfrac{7}{8}\, d\, f_s\, A \qquad (6)$$

which is the common formula for use in determining the resistance of the steel.

Also we have

$$M_c = \tfrac{1}{2}\, f_c\, b\, kd\, jd$$

or $$M_c = \tfrac{1}{2}\, f_c\, k\, j\, b\, d^2 \qquad (7)$$

or approximately

$$M_c = \tfrac{1}{6}\, f_c\, b\, d^2 \qquad (8)$$

which gives the resistance of the concrete. The resistance of the beam is in every case the lesser of the two computed resistances. That beam will, of course, be the most economical in which these two are equal. From the inspection of formulae (6) and (8), it will be seen that there is a definite ratio between the area of the steel and the area of the concrete which will give equal moments of resistance to both materials and which may be called the economical ratio.

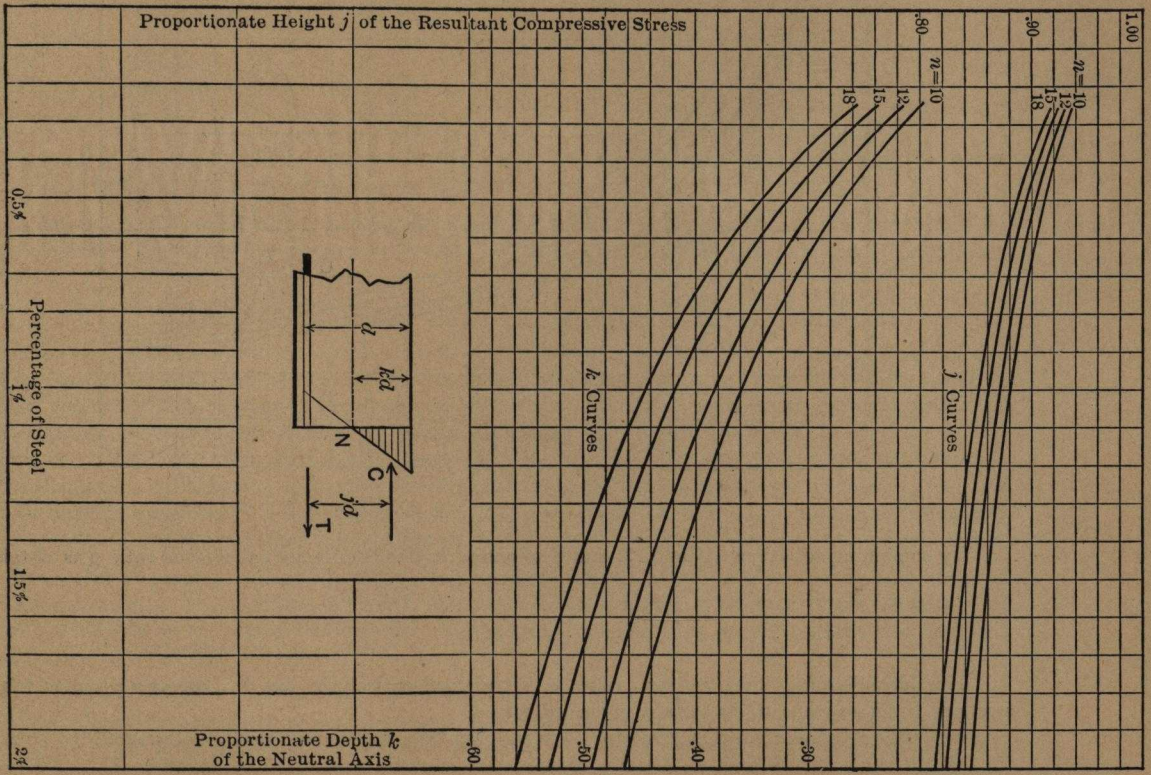

Proportionate Height j of the Resultant Compressive Stress
1.00
.90
.80
n=10
12
15
18
j Curves
k Curves
.60
.50
.40
.30
Percentage of Steel
0.5%
1%
1.5%
2%
Proportionate Depth k of the Neutral Axis
d
kd
N
C
jd
T

FIG. 2.

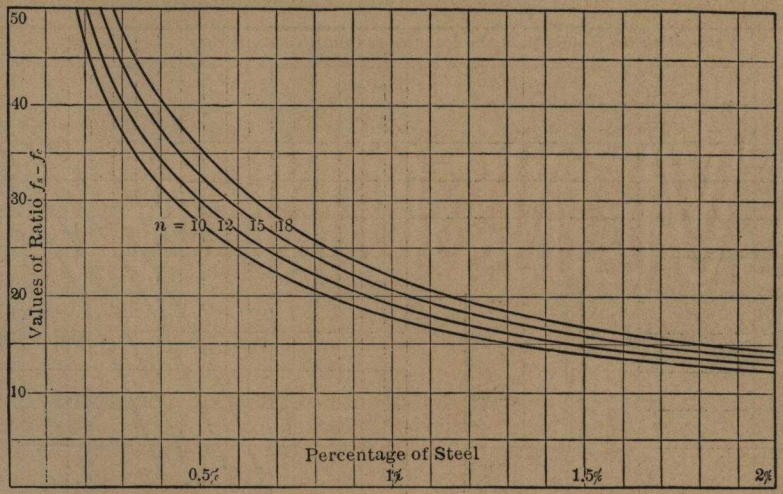


FIG. 3.

By combining equations (1) and (2) and eliminating k, this commonly called steel ratio p is obtained.

$$p = \frac{1}{2} \frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{f_c n} + 1\right)} \qquad (9)$$

This formula shows that the steel ratio, p, is governed entirely by the unit stresses assumed for the steel and concrete respectively for any given value of n.

If a value of p less than that given by (9) is adopted then the cross-section is determined by equation (6). If the value of p be greater, then the cross-section must be determined by equation (8).

In designing a beam the bending moment is the factor commonly given and the amount of steel and cross-section to be determined.

Equations (6) and (8) may be transformed for this purpose by solving for $b\ d^2$

$$b\ d^2 = \frac{M}{\frac{7}{8} f_s p} \qquad (10)$$

$$b\ d^2 = \frac{M}{\frac{1}{6}\ f_c} \qquad (11)$$

Figures 2 and 3 give a graphical solution of formulæ (3), (4) and (9) and from them may be found the unknown values of any of the equations for k, j, and p.

An inspection of figure 2 will show that the value of j varies very slightly for all practical ratios of steel to concrete. Hence the approximate value of $j = \frac{7}{8}$ in formula (6) will be seen to be ample for ordinary work.

CONTINUOUS BEAMS AND THE NEGATIVE BENDING MOMENT.

Continuous beams occur in reinforced concrete work by virtue of the fact that it is usually a monolithic structure, hence all beams must be reinforced on the upper flange over the support to provide for the negative bending moment. This is compulsory regardless of the saving effected by the use of the principles of continuous beams. A designer is apt to fall into the common error of supposing that he is on the side of conservatism when he figures a reinforced concrete beam as a simple beam and neglects top reinforcement over the support. All beams in a concrete building must be reinforced against negative bending moment with the possible exception of a few isolated lintels that may occur. A beam framing into a wall on the side of a building should have top reinforcement at the end, the same as if it were continuous beyond it.

Here it may be noted that the "Xpantrus" Bar is unique in that it amply provides for top reinforcement in all possible cases. The architect is insured against an error in detail on the part of the designer, and against carelessness on the part of the foreman or negligence of the inspector, in omitting the steel designed to take care of the negative moment.

In actual practice the computations of continuous beams are complex and long under the most favorable conditions. They are further complicated by adjoining spans occurring in different lengths and the corresponding change of cross-section of the concrete beams as well as the different combinations of live load. Even if the computations were practical the refinement attained would be unnecessary. Each beam

would have to depend for part of its strength upon several adjoining ones and hence the instability of one would affect several others. If the beams are designed as freely supported, their stability is independent of each other and the construction is safer. Moreover the designing of continuous beams along theoretical lines is impractical in all constructions where the beams are figured as T sections and this constitutes nine-tenths of all actual cases. In this case the compression flange at the center where the T effect is obtained is generally designed for some given working unit stress in the concrete. The bending moment in a theoretically continuous beam is greater in every case over the support than at the center of the span. Therefore the stress of the lower or compression flange at the support where the stem alone is available for this purpose will far exceed the safe limits of the concrete. The extra steel at the top to provide for the tensile stresses over the support will be useless if the beam is not equally as strong in the compression flange at this point.

Nevertheless there will exist some negative bending moment over the support due to deflection which must be amply provided for in some way to prevent injurious cracks and to thoroughly tie the building together. This top reinforcement provided it be properly placed will permit a slight reduction of the bending moment at the center of the span within well defined limits. To summarize, therefore, it is good practice to design concrete beams as simple beams even though entering into a monolithic structure. Some engineers require that the same amount of steel be placed over the support that is used at the center of the span. This is, of course, unnecessary where the beam is designed as practically a simple beam, the top reinforcement serving more as a tie for the whole structure. The method given here is adopted because of its almost universal use. In some cases, as in slab design, which is a special case of beam design, it is customary to use as much steel over the support as at the center of the span.

Common practice permits a reduction of the bending moment at the center of the span as follows:

Let M = Bending Moment at center of span.
W = total load on beam uniformly distributed.
l = length of span.

Then for simple beams

$$M = \tfrac{1}{8}\, W\, l$$

For continuous beams in intermediate and equal spans

$$M = \tfrac{1}{12}\, W\, l$$

For continuous beams in end or unequal spans

$$M = \tfrac{1}{10}\, W\, l$$

These values are affected by concentrated loads and cases in any way out of the ordinary require special calculations. A value of $\frac{1}{10}$ used throughout will provide ample strength in all ordinary cases. This value is used as a basis for calculating the continuous beam tables for the "Xpantrus" Bar. A value of $\frac{1}{10}$ for the coefficient will provide an actual bending moment at each support of approximately $\frac{1}{40}\ W\ l$ or one-fourth of the steel required at center of beam.

The degree to which continuity will be permitted and the method of design is in a good many cases specified in building laws or given by the engineer in charge, in which case the responsibility is shifted and the designer has no option.

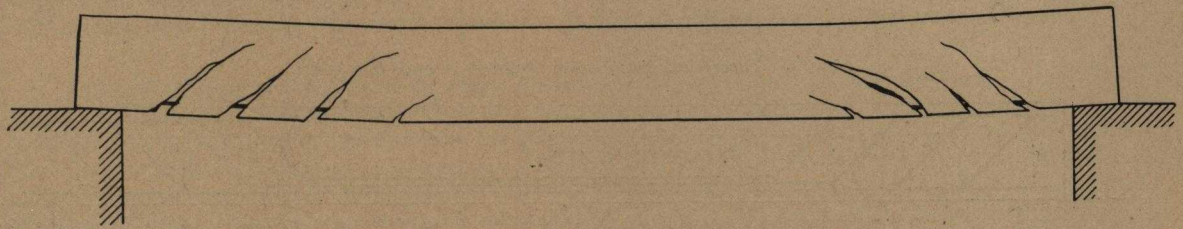


FIG. 4. Concrete beam in which shear reinforcement has been omitted. Cracks indicate direction of tensile stresses to be provided for by steel.

SHEAR AND THE DIAGONAL TENSION.

In the previous pages we have been discussing the steel reinforcement to take care of the bending moment. At the center of the span, this was placed horizontally near the bottom of the beam and near the top over the support. Of equal importance is it to have the beam reinforced against shear or the diagonal tension in the web. In the case of a reinforced concrete beam the vertical shear combines with the horizontal and produces a diagonal tension, indicated in figure 4 by the cracks in the beam, as well as a diagonal compression at right angles to same. In reality concrete in shear is approximately one-half as strong as in compression and this would be amply sufficient to take care of the vertical shear were it not for the diagonal tension produced.* In the following discussion by the term shear is meant the tendency to slippage of the particles past each other in one plane, which is the sense in which it is used in all books

*Prof. Talbot of the University of Illinois in *Engineering News* of Feb. 15, 1906; Vol. LV., No. 7, page 172.

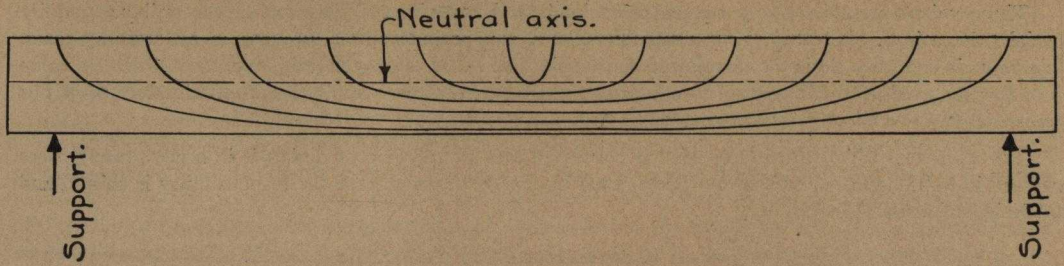


FIG. 5. **Theoretical distribution of tensile stresses in a beam.**

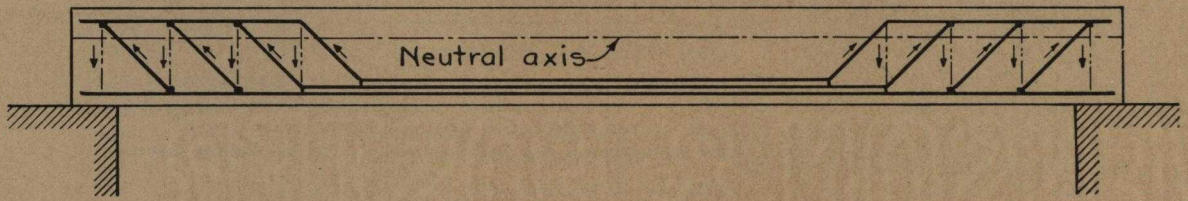


FIG. 6. **Pratt Truss effect where "Xpantrus" reinforcement is used.**

on the mechanics of material. Because the value of the one depends upon that of the other, the term reinforcement against shear is used synonymously with reinforcement against diagonal tension. Probably more beams fail because of insufficient reinforcement against the diagonal tension than by any other means. Figure 4 illustrates the failure of a beam in which shear reinforcement is omitted and the cracks shown indicate the direction of the tension which will always be at right angle to the cracks at any point. Steel rods may be used as reinforcement for this purpose to great advantage. This has been generally recognized from the first introduction of concrete-steel. No beam should be designed without a careful investigation of the shear and the reinforcement to take care of it. The essential principles governing shear design are well defined and generally recognized in practice.

Inclined Versus Vertical Shear Members.

It is obvious from figure 4 that the shear members or stirrups to be most economical should be inclined 45° to the horizontal. This is especially so near the support where the maximum shear occurs. The theoretical distribution of the stresses in the beam is given in figure 5 from which may be seen again the necessity of inclined stirrups for correct reinforcement. A discussion of the distribution of these stresses cannot be given here owing to our limited space, but it may be found in numerous text-books dealing with the mechanics of reinforced concrete beams. Where vertical stirrups are used a 30% greater area of steel is required for web reinforcement, as will be shown when the common method of calculation is discussed. The inclined stirrup possesses numerous other advantages over the vertical which will now be pointed out.

The Properly Reinforced Concrete Beam a Pratt Truss.

Rational inspection will teach that the diagonal stresses to be taken care of at all must be transmitted to the main tension and compression members as in the case of a steel truss. On the lower or tension side this can only be effected by a rigid tie to the lower bars. On the upper or compression side of the beam the stirrup or shear members must be long enough to develop their full value by means of the bond attained with the concrete *ABOVE THE NEUTRAL AXIS*. It is obvious that from practical limitations governing the depth of beams this is very seldom possible, hence the only effective method is to rigidly anchor the shear member on the compression side. Where top reinforcement occurs these shear members must be effectively tied to the upper bars *AS WELL AS TO THE LOWER HORIZONTAL MEMBERS*. But as it has been shown in the article dealing with the negative bending moment that practically all concrete beams must be reinforced near the top over the support, it follows that this method should be adopted in all reinforcement. In respect to shear reinforcement these ideal conditions are only attained in the "Xpantrus" Bar. Inspection will show the shear members rigidly attached to the main members both at the compression and at the tension sides of the beam. The full value of the steel in any rational design is thus assured. The Pratt truss effect thus produced is illustrated in figure 6 which shows the way the complex stresses in a concrete beam are cared for where "Xpantrus" reinforcement is used. Numerous experiments have shown that if the shear members be rigidly attached to the main members the strength of the beam is increased between 20 and 30 per cent. Shear members which are loose or which do not extend well into the compression side of the beam will invariably cause the failure of the beam by their slippage.

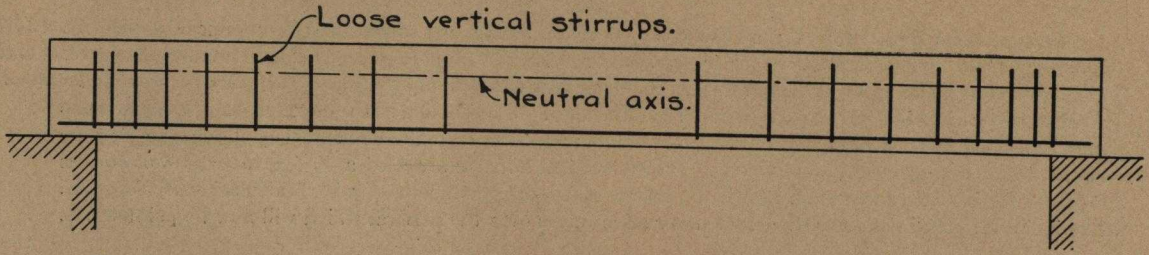


FIG. 7. A common method of reinforcement with loose vertical stirrups. Their value is uncertain as their stresses must be transmitted to the main tension members through the medium of the concrete at the base. The secondary stresses thus developed are complicated and indeterminate. Under full size test, their tendency is to slip along the main tension members at their base.

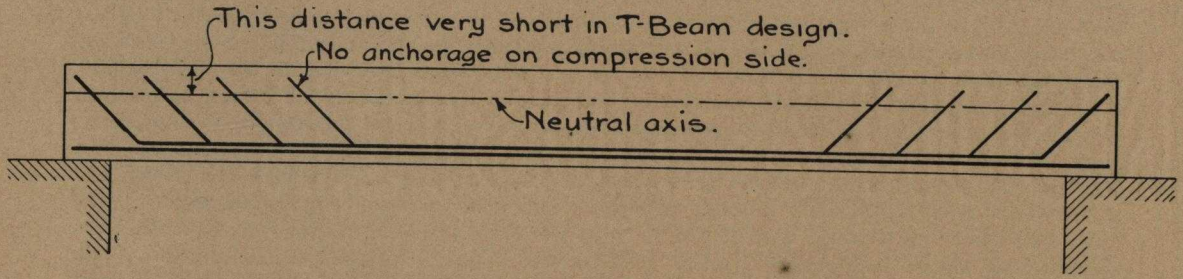


FIG. 8. A common method of reinforcement. Very inefficient. The only anchorage of the shear members on the compression side is their bond with the concrete above the neutral axis. They are invariably too short to develop their full value by means of this adhesion.

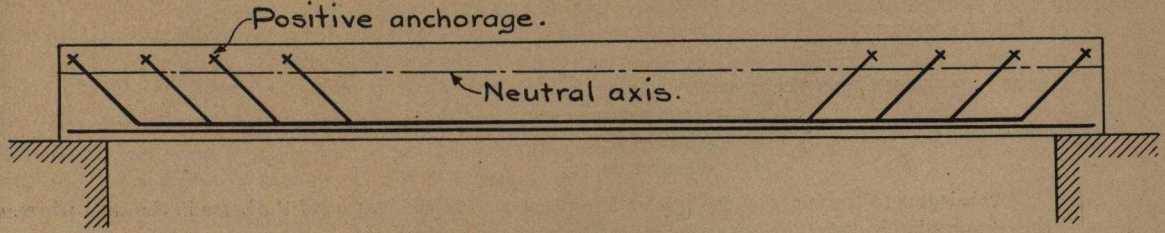


FIG. 9. Design with positive anchorage of shear members above the neutral axis.

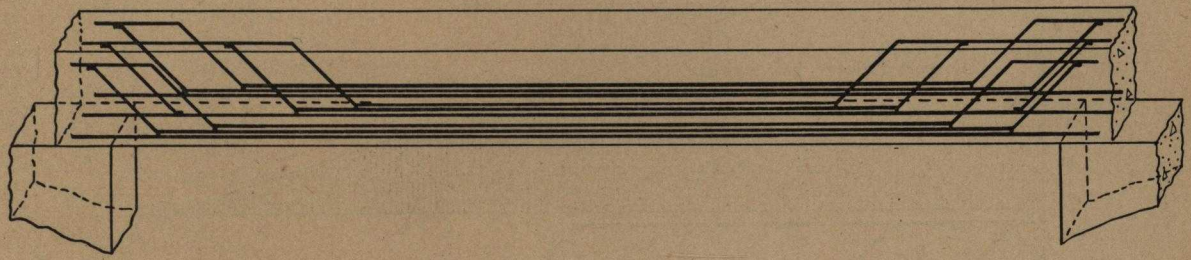


FIG. 10. An "Xpantrus" bar unit frame. The ideal reinforcement. Positive anchorage of shear members both to the main tension members as well as in the compression. No displacement possible in the field. Ordinary inspection assures their full value and correct distribution.

The Unit Shear

Unlike in the case of a beam of homogeneous material the maximum shear in a vertical plane in a reinforced concrete beam may be shown to be:

$$v = \frac{V}{b\,jd}$$

when v = maximum unit shear.

V = total vertical shear.

b = width of beam.

jd = effective depth.

This is due to the fact that the tension is concentrated at the bottom of the beam in the steel whereas the compression is distributed over the concrete above the neutral axis.

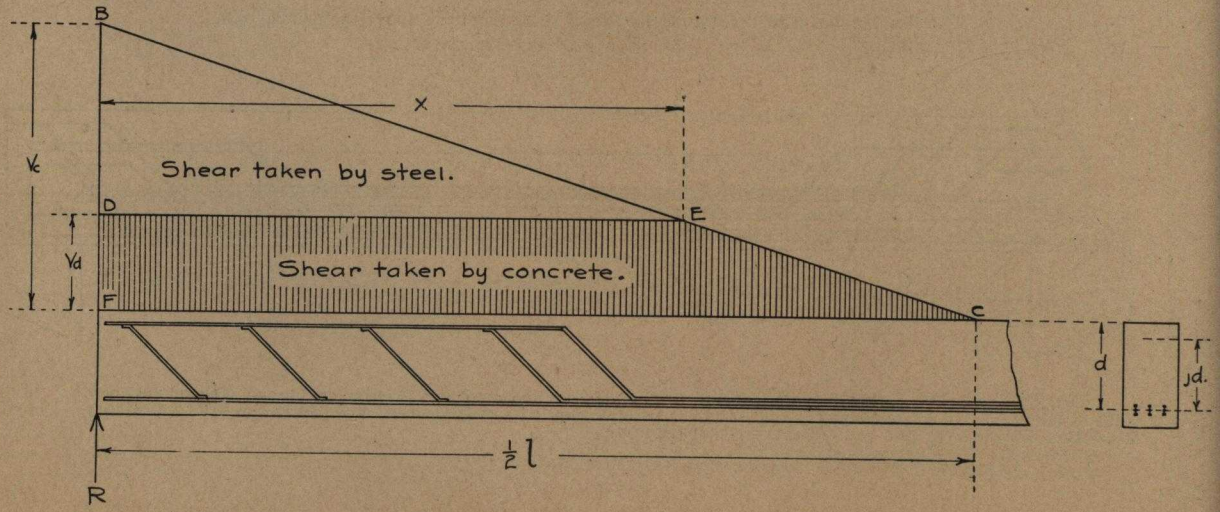


FIG. 11.

Calculations for Shear Reinforcement

Good practice regulates that the cross-section of a beam should be such that the maximum unit shear at the support should not exceed 150 pounds per square inch of effective cross-section. Referring to figure 11 the maximum shear should not exceed 150 $b\ jd$. If in a T-beam the stem is narrow compared to its height, this value should educe to 100 $b\ jd$. In beams where the web is not properly reinforced in shear, it will be found advisable to reduce this considerably. Of the shearing stress the concrete may be safely allowed to take 50 pounds per square inch. The remainder must be taken care of by the steel.

As the web members are generally of the same cross-section, it is customary to ascertain the total shear to be taken care of by the steel and to provide sufficient steel area for it. By properly spacing the shear members, the distribution of the steel may be regulated.

The following simple method will illustrate how this may be done in practice:
Referring to figure 11, let

V_c = Maximum shearing stress per square inch at support $= \dfrac{R}{b\ jd}$

V_d = permissible unit shear in concrete.
R = reaction at support.
b = width of beam.
jd = effective depth of beam.
x = portion of length in inches requiring shear reinforcement.
l = span of beam in inches.
f_s = unit stress in steel.
a = aggregate area of shear members required in one half of beam.

From the figure we have

$$\frac{V_c - V_d}{V_c} = \frac{x}{\frac{l}{2}}$$

whence $x = \dfrac{l\,(V_c - V_d)}{2\,V_c}$

Let A_1 = area of $\triangle\ B\ D\ E$. This may be regarded as the total shear taken by the steel in one inch of width. Hence

$$A_1 = \left(\frac{l\,(V_c - V_d)}{2\,V_c}\right)\left(\frac{V_c - V_d}{2}\right)$$

The total vertical shear in one half of the beam to be taken by the steel equals

$$A_1\,b = \frac{b\,l\,(V_c - V_d)^2}{4\,V_c}$$

which represents the total stress to be taken care of by the steel.

For the stresses in shear members inclined 45° the worst assumption would be that the full diagonal tension was required to be carried by them. The diagonal tension for this case is taken as equal to the vertical shear required to be taken by the steel.

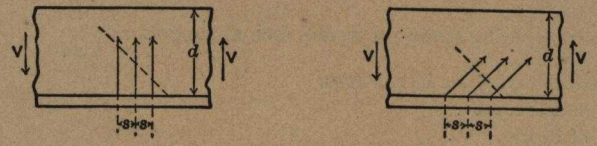


FIG. 12.

Referring to figure 12, the stress that each stirrup is required to take equals the diagonal tension at the point in question distributed over the distance at right angles between stirrups.

This distance is given by $s \times cos.\ 45°$.

The stress in the stirrups is therefore given by:

The diagonal tension at the point in question $\times$ $s.\ cos\ 45°$.

The total stress in all the inclined stirrups therefore equals the total vertical shear to be taken care of by the steel multiplied by the cosine of 45°.

If vertical stirrups are used the total stress in the stirrups equals the total vertical shear to be taken care of by the steel. This method of computing the shear conforms to the recommendations of the "Joint Committee" as well as the method supported by Profs. Turneaure and Maurer of the University of Wisconsin in their book on "Principles of Reinforced Concrete Construction."

For inclined shear members the above may now be expressed algebraically as follows:

$$a f_s = \frac{b\,l\,(V_c - V_d)^2}{4\,V_c} \cos. 45°$$

hence $$a = \frac{b\,l\,(V_c - V_d)^2}{5.6\,V_c f_s} \qquad (12a)$$

Where $V_c = 150$, $V_d = 50$, and $f_s = 16{,}000$, this equation reduces to

$$a = 0.000744\,b\,l \qquad (12)$$

If $V_c = 100$, the other quantities remaining as above, the equation reduces to

$$a = 0.000279\,b\,l \qquad (13)$$

In very important cases the distribution may be arrived at by dividing the triangle *B D E* into equal areas, which indicate the proportion of steel for that section. It is sufficient in practice to approximate this distribution as the calculations are only approximate. It is safe to say that the results are on the side of safety. In general if inclined members are used, the spacing should not exceed the effective depth of the beam. If vertical members are used, a closer spacing will be required, generally one-half the effective depth.

It is therefore well to note here that if vertical shear members are used, equation (12) becomes

$$a = 0.00104\,b\,l \qquad (14)$$

and equation (13) becomes

$$a = 0.000391\,b\,l \qquad (15)$$

whence it may be noted that there is an economy of 30% effected by the use of inclined members for shear reinforcement.

In any case whether vertical or inclined shear members are used, they should extend well into the compression flange to insure their full development. Where loose stirrups or any unanchored shear members are used, they should be investigated for bond strength and this full strength must be developed *ABOVE THE NEUTRAL AXIS.*

Calculation of Shear Members for "Xpantrus" Bar.

The spacing of the shear members for the "Xpantrus" Bar is fixed by the height of rise to which the bar is expanded. It has been already shown that the amount of steel required for shear reinforcement varies with the distance from the support where the greatest amount is needed. On the other hand, the steel required to reinforce against bending moment varies with the distance from the center of the span where

the full amount only is required. By treating all the bars in a beam as a unit, the "Xpantrus" System provides for this variable cross-section of the steel in a beam. Figure 18 illustrates how this is effected. The greatest amount of shear reinforcement is obtained near the support, while at the center the full amount is obtained for reinforcement against bending moment. The economy obtained by this method of distribution of the steel cannot be overestimated. Practical men will at once realize its importance. The hearty reception that the "Xpantrus" Bar everywhere has received is an indication of its worth.

For purposes of standardization the "Xpantrus" Bar is recommended in combinations of three, five and seven bars to a unit frame. By the use of these units it is possible to carry in stock large numbers of the cast malleable iron chairs heretofore mentioned as essential in the complete assembly of the "Xpantrus" unit frames. In no other way would it be possible to carry a large assortment of sizes in stock and the varying cross-sectional areas of the bars permit any desired area of steel to be obtained.

The maximum value of shear reinforcement attainable in the "Xpantrus" Bar may be easily determined by ascertaining the variable amount of steel needed for the bending moment. The method adopted for this purpose is the same as that used to design the lengths of cover plates in the flanges of plate girders. The formula here given applies only to uniformly loaded beams.

Let A = total area of steel at center of span in square inches.

l = length of span in feet.

x_1, x_2, x_n, etc. = length in feet of unexpanded portion of bar considered. x_1 has the shortest unexpanded portion.

A_1 = total area of steel no longer available for bending moment resistance after the bar in question is expanded. In structural steel design of a plate girder this area corresponds to the total area of all cover plates up to and including the one in question beginning with the outside one.

From structural steel design we have

$$x_n = l \sqrt{\frac{A_1}{A}}$$

Applied to the three, five and seven bar units, the lengths of the expanded portions thus determined are shown in figures 15, 17, and 18. The area of steel available for reinforcement against diagonal

tension under the distribution called for in these standards is in every case amply strong enough to take care of the loadings in the total load tables hereinafter submitted. A designer need only avail himself of the standard assembly to be assured of sufficient reinforcement in this respect.

It should be noted that this diagonal reinforcement as well as that at the top of the beam over the support, is accomplished by utilizing the steel in the lower flange which is no longer needed there. No additional material is required for this function. The economy of this type of reinforcement will be admitted by any observing person. This economy has not been attained by sacrificing any of the value of the steel because it is theoretically correct, therefore permissible as well as highly desirable. The method of attachment of these shear members reduces the cost of installation to a minimum. These points should be strictly taken into account when price is being considered.

GIRDERS.

In a floor construction a girder occurs where one or more beams frame into another. In addition to these concentrated loads the girder will carry a uniform load of at least its own weight. Any one familiar with the designs of beams of homogeneous material, such as a steel beam, can readily determine the maximum bending moment in any floor girder and the design of the reinforced concrete member proceeds as for uniformly loaded beams. It is best for this purpose to transfer the concentrated loads into corresponding uniform ones, to be added to the uniform load of the girder itself. The total load thus computed may be used to select the section of a beam from the total load tables hereinafter given.

The question of shear should be investigated, but it will not prove to be the controlling factor as will be shown to be the case in T beams which will now be taken up. In general a standard arrangement of shear members will cover even the worst cases. It should not be forgotten that the adjoining slabs transfer part of their load direct to the girder and discerning engineers will give this a due allowance. Anyone using the "Xpantrus" Bar and desiring a special arrangement of shear members other than the standard uniform load combination may readily secure same. Page 50 shows sample data sheet illustrating how to order special shear bar arrangement. Figure 16 illustrates a special arrangement of shear members at the direction of the customer.

T-BEAMS.

Probably the most common form of beam an engineer is called upon to design is the T-beam. In this case the slab forming part of the floor system is considered as part of the beam and entered into the calculations as such. The saving in concrete thus effected is obvious. It is sanctioned by good practice. It is, of course, only possible in monolithic structures. Great care must be exercised in the field to see that the pouring of the concrete is continuous in these cases. For this reason T-beams should be noted as such in plans intended for the construction force that they may be governed accordingly.

In the design of T-beams it is first necessary to ascertain the width of the flange, b, figure 13, allowable for compression purposes. The "Joint Committee" of the four societies recommended:

a. It shall not exceed one-fourth of the span length of the beam.

b. Its overhanging width on either side of the web shall not exceed four times the thickness of the slab.

The Prussian Specifications for 1904 require that it shall not exceed one-third the span of the beam and as this conforms more with common practice it was used in the compilation of the tables hereinafter submitted.

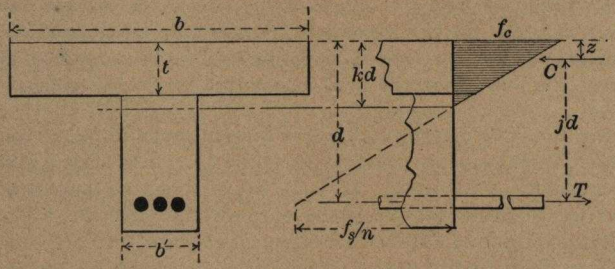


FIG. 13.

If the neutral axis falls above the lower edge of the slab, the beam is designed as a rectangular beam of width b and depth d. In this case all the formulæ of rectangular beams apply, and the problem is a simple one. Where the neutral axis falls below the slab the method is somewhat more complicated.

The following approximate method will be found to give satisfactory results in the latter case:

Using same notation as heretofore, if f_c=compressive working stress in extreme fibre of concrete, we may with safety assume $0.45 f_c$ as the average stress in the compressed part of a T-beam. In order to keep the percentage of steel within safe limits, the following equation must be satisfied:

$$f_s A = 0.45 f_c b t$$

where t = thickness of slab.

This equation is based on the well known mechanical principle that the total tensile stress in the steel equals the total compressive stress in the concrete. It will be found in practice that invariably a T-beam is stronger in compression than in tension, so that finally the design of a T-beam reduces itself to the computations of the steel required, the stress being proportioned for the proper packing of the steel. This simplifies the calculations considerably. It should be noted that for the best results the value of d should be 3½ or 4 times the value of t. For the determination of the position of the neutral axis, the formula given for rectangular beams will give sufficient accuracy for all practical purposes.

More exact formulae for T beams when the neutral axis lies in the stem are herewith submitted:

The following formulae neglect the compression in the stem.

Position of neutral axis,

$$k d = \frac{2 n d A + b t^2}{2 n A + 2 b t}.$$

Position of resultant compression,

$$z = \frac{3 k d - 2 t}{2 k d - t} \cdot \frac{t}{3}.$$

Arm of resisting couple,

$$j d = d - z.$$

Fiber stresses,

$$f_s = \frac{M}{A j d}. \qquad f_c = \frac{M k d}{b t (k d - \frac{1}{2} t) j d} = \frac{f_s}{n} \cdot \frac{k}{1-k}.$$

The following formulae take into account the compression in the stem; they are recommended where the flange is small compared with the stem.

Position of neutral axis,

$$k\,d = \sqrt{\frac{2\,n\,d\,A + (b-b')\,t^2}{b'} + \left(\frac{n\,A + (b-b')\,t}{b'}\right)^2} - \frac{n\,A + (b-b')\,t}{b'}.$$

Position of resultant compression,

$$z = \frac{(k\,d\,t^2 - \frac{2}{3}\,t^3)\,b + [(k\,d-t)^2\,(t + \frac{1}{3})\,(k\,d-t)]b'}{t\,(2\,k\,d-t)\,b + (k\,d-t)^2\,b'}$$

Arm of resisting couple,

$$j\,d = d - z.$$

Fiber stresses,

$$f_s = \frac{M}{A\,j\,d}. \qquad f_c = \frac{2\,M\,k\,d}{[(2\,k\,d-t)\,b\,t + (k\,d-t)^2\,b']\,j\,d}.$$

T-beams require careful investigation for diagonal tension in the stem. It will be found that this will be the governing factor in a good many cases. All the formulæ deduced under the article on shear are applicable to T-beams. For this purpose the effective cross-section is taken as $b'\,jd$.

SLABS.

The "Xpantrus" Bar is applicable to heavy slabs and for this purpose is unexcelled. The same qualities of merit will distinguish it here as in the case of rectangular beams. A typical floor slab is nothing more or less than a rectangular beam and may be figured as such an one twelve inches in width.

A small amount of transverse reinforcement has been found necessary in slab work to prevent cracks and bind together the entire structure. Experience teaches that ½" or ⅜" diameter rods spaced at the one-third points of the span is sufficient.

It is customary to design slabs as continuous over the support. The bending moment at center may be taken at $\frac{W\,l}{12}$. For this reason the slabs should be properly reinforced over the support. The reinforcement should be positive to be effective. As was shown in the case of rectangular beams, the "Xpantrus" Bar provides a method both positive and economical. In its provision against the negative bending moment, the "Xpantrus" System is unique and unequaled by any other system yet devised.

Rectangular Slabs Approximating a Square

Rectangular slabs approximating a square constitute a special case of slab design. When the length does not exceed the breadth by more than 50%, transverse reinforcement may be used to advantage. In such case the transverse reinforcement may be considered to carry a portion of the load. The concrete in the slab is designed for the compressive stresses in accordance with the assumptions for the tension side. The compression in one direction is assumed as not affected by that in the opposite direction.

The following method will give results on the safe side:

Let r = proportion of load carried by transverse reinforcement.
l = length of slab.
b = breadth of slab.

$$r = \frac{l^4}{l^4 + b^4}$$

For various ratios of l/b the values of r are as follows:

Values of l/b	1	1.1	1.2	1.3	1.4	1.5
" " r	0.50	0.59	0.67	0.75	0.80	0.83

Using the values above specified, each set of reinforcement is to be calculated in the same manner as slabs having supports on two sides only, but the total amount of reinforcement thus determined may be reduced 25% by gradually increasing the rod spacing from the third point to the edge of slab.

BOND.

The question of bond is one which the designer using the "Xpantrus" Bar need have no concern about whatsoever. The bond attained by the web members when enmeshed in the concrete is perfect.

In the use of plain round rods or bars, the bond question becomes a problem and is an important consideration both in the main tension and in the web members.

EXAMPLE. It having been determined by the foregoing principles of design that 3 square inches of steel are needed in the main tension member of a beam, the problem confronting the designer is, which shall be used

1—2" diameter, round.
2—1⅜" " "
3—1⅛" " "
4—1" " " etc.

All other things being equal, it is obvious the fewer the number of bars the cheaper the handling, hence the most desirable. The question of shear having been decided, there remains yet the bond to be investigated.

Let u = bond stress per unit area of bar.
V = total shear at any point.
$\frac{7}{8}\,d$ = approximate effective depth of beam.
Σ sum of the perimeters of all bars.

The "Joint Committee" recommends the following formula:

$$u = \frac{8}{7}\,\frac{V}{d\ \Sigma}$$

A working bond stress is commonly specified between 60 and 80 pounds per square inch.

By letting u in the above formula equal 60 or 80, as the case may be, the quantities V and d having been previously determined, Σ, the sum of the perimeters, may be determined and the above problem can be solved.

Specifications commonly call for a minimum distance between rods of 2½ times their diameter and this rule should be followed in investigating the packing of the steel in the beam.

This formula also applies to the shear members or stirrups. In this case it should be noted that the full value of the stirrup must be developed on the compression side of the neutral axis by means of the bond, unless rigidly anchored there. On the tension side, as has been previously shown, it should be tied rigidly to the main tension members. These requirements are no where better provided than in the "Xpantrus" Bar.

If the unit stress in the steel be taken at 16,000 pounds and the working bond stress at 80, the bar would have to be embedded $\frac{16{,}000}{4 \times 80} d$ or a length equal to 50 times its diameter.

It should also extend this distance beyond the support to insure the full transmission of its stresses into the adjoining span. A large tonnage of steel is thus being imbedded constantly by contractors for this very function alone. The performance of this function by the steel is absolutely unavoidable whether simple or continuous beams are encountered as has been demonstrated in preceding discussions. The "Xpantrus" Bar effects an appreciable saving in this respect in all concrete beam construction. The method of providing for continuity has been fully described and its value will be clearly grasped.

DOUBLE REINFORCEMENT.

It is sometimes impractical to provide sufficient concrete to take care of the total compression in a beam, in which case steel may be used to advantage. Nowhere is the adaptability of steel in concrete so marked as in this case, when it performs at a high unit stress the very function of the concrete which is however handicapped by its comparatively low unit stress. Steel in compression can only be used at such a low unit stress that it is uneconomical and should not be used except where unavoidable.

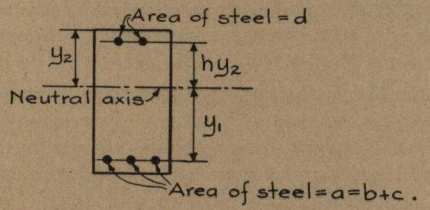


FIG. 14.

The average discussions of double reinforcement given in text-books or papers before engineering societies are so complex and so long as to be of little value to the designer. Moreover the results attained do not appear to warrant the refinement. Particularly is this true when it is possible to arrive at it by more direct and simple methods which give results on the side of safety.

Let a = required area of steel determined by the given depth, bending moment, and unit stress in the lower or tension side.

b = required area of steel in lower or tension side determined by the working strength of the concrete.

$c = a - b$ = excess area of steel in lower flange.

d = area of steel in compression side required to be computed.

It can be seen at a glance that the top steel d, must counteract the excess steel c in the lower flange. These two areas, c and d, will be to each other inversely as their distances from the neutral axis or referring to figure 14

$$\frac{d}{c} = \frac{y_1}{h\, y_2}$$

$y_1 + h\, y_2$ may be assumed as $0.9\ (y_2 + y_1)$ in all approximate computations. From inspection it will be seen that the area of compressive reinforcement is governed by the position of the neutral axis which in turn depends on the percentage of the compressive to the tensile steel. Provided that the area of the compressive steel is less than 75% of the tensile, sufficiently accurate results will be attained by the formula

$$d = 1.75\, c$$

Where there are a large number of such beams needing compressive reinforcement, more exact formula might be used to advantage. The investigator is referred to the report of the "Joint Committee" where such may be found.

Shear members should be attached to the steel in compression to properly bind it to the concrete and provide for the extra shear. For this reason an "Xpantrus" Bar reversed forms the suitable and reliable method. Numerous devices will at once suggest themselves to the practical man to hold the bar in position and attain the same results as in the ordinary construction. When plain rods are used for double reinforcement, they should be carefully investigated for the bond stresses.

COLUMNS.

The design of reinforced concrete columns will be found more empirical than the various designs of beams heretofore given. In general it is regulated by common practice, using in every case safe unit stresses. It is customary to insert steel on the periphery of concrete columns to take part of the compressive stress as well as to take the excessive and uncertain stresses due to eccentric loading.

The design of columns resolves itself into the design of hooped and unhooped columns. In either case the following broad principles apply:

a. The ratio of unsupported length of a column to its least width should not be greater than 15.

b. The effective area of a column shall be taken as the area within the protective covering. The two outside inches of the column is regarded as fire protection only.

UNHOOPED COLUMNS. In this case the reinforcement is constituted of longitudinal bars or rods with sufficient lateral support to be securely held in place until the concrete has set. The design, if such it may be called, constitutes (1) in proportioning the columns in width to length as above required; (2) The working stress in the concrete shall not exceed 500 pounds per square inch of effective cross-section. The steel is proportional for a unit stress of 7,500 pounds per square inch. The value of the ratio of the moduli of elasticity is assumed at 15.

HOOPED COLUMNS. To M. Considére, a French engineer who has made exhaustive experiments in reinforced concrete, is due the development of this style of column reinforcement. In brief it consists of binding the column laterally with bands or hoops together with the longitudinal bars above mentioned, or by means of structural forms which in themselves are sufficiently rigid to act as columns. The effect of hooping is to increase the toughness of the column by reinforcing against lateral bulging. Much higher unit stresses can then be attained in the concrete and consequently in the steel. By this method the unit stresses of the concrete may be increased to 1,000 pounds per square inch and that of the steel to 15,000 pounds per square inch. The advantage of this method of reinforcement is obvious.

It should be noted that in hooped columns the effective cross-section of the concrete is enclosed within the hooping only. If this is not sufficient to carry the load, insert longitudinal bars inside the hooping to carry the excess at a unit stress of 15,000 pounds per square inch.

The percentage of reinforcement in hooped or unhooped columns should range between 1% and 2% of the effective area of the concrete. No part of the hooping shall be considered as taking any of the direct load of the column. If r is the radius of the hooping then $\frac{r}{50}$ will express the area or cross-section of the band. The pitch center to center should not exceed $\frac{2}{5}r$. The width of the band should be as great as possible, but the thickness should be sufficient to maintain the stiffness or spring of the hooping. For various practical reasons the width of the band should not exceed $\frac{1}{5}r$ but as close as possible to this ratio.

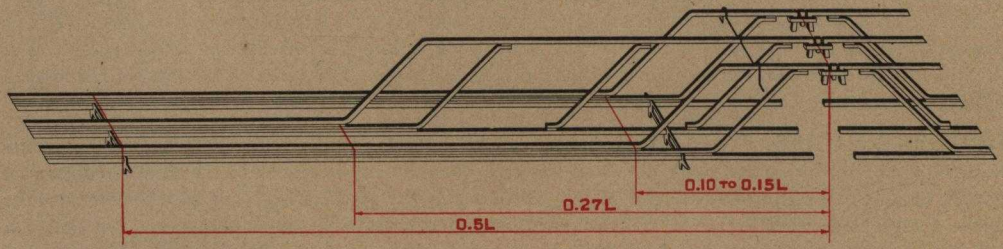


FIG. 15. "Xpantrus" System.—Standard three-bar unit frame. Showing proportion of length expanded.

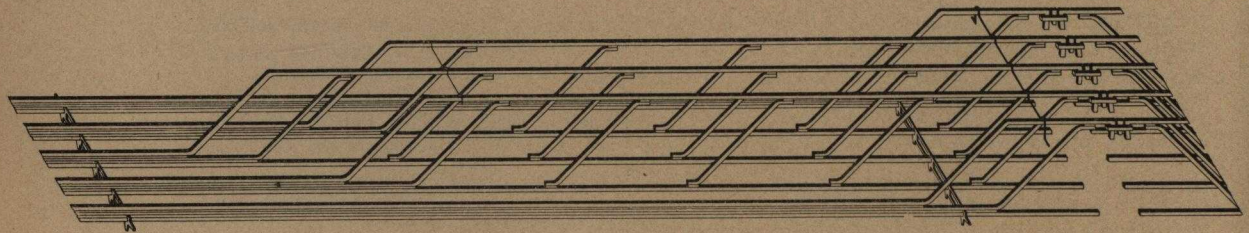


FIG. 16. Special arrangement of shear members at direction of purchaser.

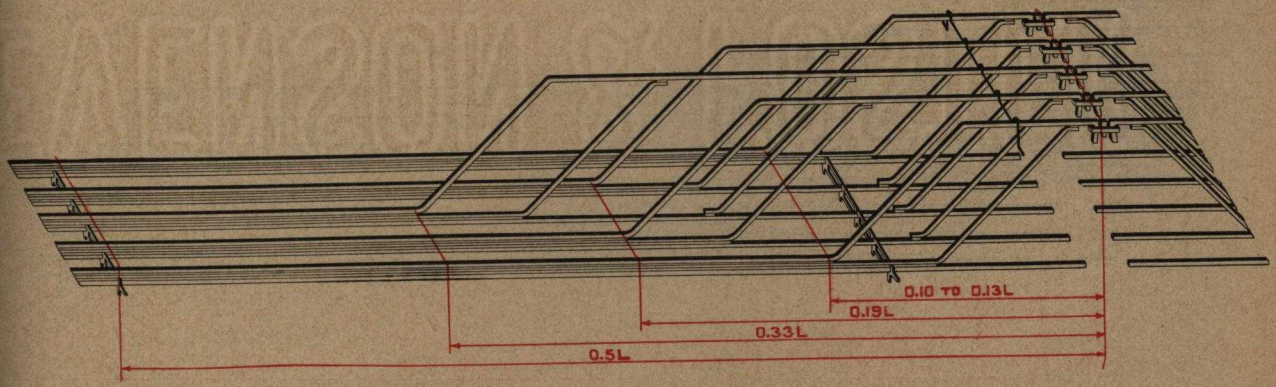


FIG. 17. Standard five-bar unit frame showing proportions of length expanded. Note the system of chairs and spacers accompanying the standard frames. Ordinary precaution will assure the theoretical number and position of all bars imbedded in a concrete beam. The purchaser is assured of veritable fool-proof construction. All points being considered, the "Xpantrus" system is the highest development of concrete reinforcement yet devised.

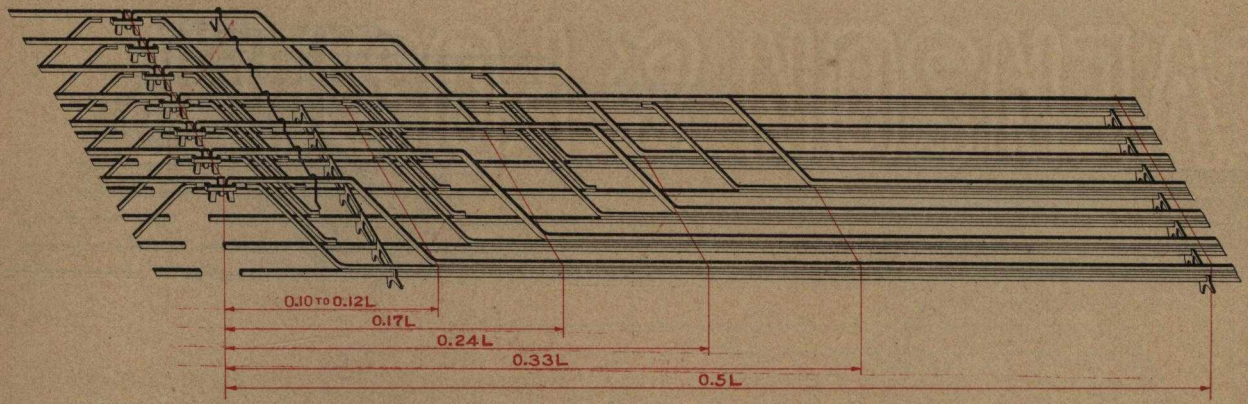


FIG. 18. Standard seven-bar unit frame showing the proportion of length expanded.

Note the varying cross-section of main tension members and the saving of steel effected thereby.

Note the economical method of providing for continuity. The rigid frames require the minimum cost for installation. The "Xpantrus" System is in every way the most economical reinforcement in the market. It utilizes steel that goes to waste when other bars are used.

SUMMARY OF THEORY AND METHODS OF DESIGN.

Notation

For the convenience of the user of the following summary, we repeat here the foregoing notation.

Rectangular Beams

f_s = tensile unit stress in steel.
f_c = compressive unit stress in concrete.
E_s = modulus of elasticity of steel.
E_c = modulus of elasticity of concrete.

$$n = \frac{E_s}{E_c}$$

M = bending moment in general.
M_s = moment of resistance of steel.
M_c = moment of resistance of concrete.
A = steel area.
b = breadth of beam.
d = depth of beam to center of steel.
k = ratio of depth of neutral axis to effective depth, d.
z = depth of resultant compression below top.
j = ratio of lever arm of resisting couple to depth, d.
$jd = d - z$ = arm of resisting couple.

$$p = \text{steel ratio} = \frac{A}{b\,d}$$

Continuous Beams

W = total load uniformly distributed.

Shear

R = reaction = vertical shear at support.

V_c = maximum shearing stress per square inch at support $= \dfrac{R}{b\,jd}$

V_d = permissible unit shear in concrete.
l = span of beam.
a = aggregate area of shear members required in one half of beam.

T-Beams

b = width of slab available for compression flange.

b' = width of stem.

t = thickness of slab.

Slabs

r = proportion of load carried by transverse reinforcement.

l = length of slab.

b = breadth of slab.

Bond

u = bond stress per unit area of bar.

Σ sum of all perimeters of bars.

Double Reinforcement

a = required area of steel in the lower or tension determined by the given depth, bending moment, and unit stress.

b = required area of steel in lower or tension side determined by the working strength of the concrete.

$c = a - b$ = excess area of steel in lower flange.

d = area of steel in compression flange.

y_1 = distance between center of steel in lower flange and neutral axis.

y_2 = distance between top of beam and neutral axis.

$h\ y_2$ = distance between center of steel in compression flange and neutral axis.

Columns

r = radius of hooping.

FORMULAE.

Rectangular Beams.

Position of neutral axis.

$$k = \sqrt{2\,p\,n + (p\,n)^2} - p\,n \qquad (3)$$

Arm of resisting couple

$$j = 1 - \tfrac{1}{3}\,k. \qquad (4)$$

When $f_s = 15{,}000$ to $16{,}000$ and $f_c = 600$ to 750, j may be taken at $\tfrac{7}{8}$ and the value of k at $\tfrac{3}{8}$.

Moment of Resistance of Steel.

$$M_s = jd\,f_s\,A \qquad (5)$$

or approximately

$$M_s = \tfrac{7}{8}\,d\,f_s\,A \qquad (6)$$

Moment of Resistance of Concrete.

$$M_c = \tfrac{1}{2}\,f_c\,k\,j\,b\,d^2 \qquad (7)$$

or approximately

$$M_c = \tfrac{1}{6}\,f_c\,b\,d^2 \qquad (8)$$

For purposes of design these formulæ are transformed into

$$b\,d^2 = \frac{M}{\tfrac{7}{8}\,f_s\,p} \qquad (10)$$

$$b\,d^2 = \frac{M}{\tfrac{1}{6}\,f_c} \qquad (11)$$

The value of p may be found from the formula

$$p = \tfrac{1}{2}\,\frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{f_c\,n} + 1\right)} \qquad (9)$$

The values of k, j, and p may be found in figures 2 and 3.

Continuous Beams

For simple beams the bending moment should be taken at

$$M = \tfrac{1}{8}\, W\, l$$

For continuous beams in intermediate and equal spans and slabs

$$M = \tfrac{1}{12}\, W\, l$$

For continuous beams in end or unequal spans

$$M = \tfrac{1}{10}\, W\, l$$

This latter is recommended if it is desired to use a constant coefficient throughout a building.

Shear in Uniformly Loaded Beams

In any beam where the web reinforcement is complete and effective, the cross sectional area is taken from

$$R = 150\, b\, jd.$$

Where, as in the case of some T-beams, the stem is apt to be slender, the cross section is given by

$$R = 100\, b\, jd.$$

The area of steel required for inclined shear members in one-half of beam is given by

$$a = \frac{b\, l\, (V_c - V_d)^2}{5.6\, V_c\, f_s} \qquad (12a)$$

Where $V_c = 150$, $V_d = 50$, $f_s = 16{,}000$, this equation reduces to

$$a = 0.000744\, b\, l \qquad (12)$$

Where $V_c = 100$, other quantities remaining as above, it reduces to

$$a = 0.000279\, b\, l \qquad (13)$$

If vertical shear members are used, the aggregate area required becomes

$$a = \frac{b\, l\, (V_c - V_d)^2}{4\, V_c\, f_s}$$

Equation (12) becomes

$$a = 0.00104\, b\, l \qquad (14)$$

Equation (13) becomes

$$a = 0.000391\, b\, l \qquad (15)$$

T-Beams

Design the stem for the steel required, taking into account the shear in accordance with the principles given for rectangular beams.

The width of flange available for compression design is given by

$$b = \tfrac{1}{3}\, l$$

or $$4\,t > \frac{b - b'}{2}$$

The area available for concrete should satisfy the following approximate equation:

$$f_s\, A = 0.45\, f_c\, b\, t.$$

More exact formulæ are submitted under the discussion for T beams and designers should refer to them if the approximate formula here given fails to satisfy the requirements.

Slabs

Design as for rectangular beams.

For continuous slabs, use bending moment.

$$M = \tfrac{1}{12}\, W\, l.$$

When the length does not exceed the breadth by more than 50%, transverse reinforcement may be used.

$$r = \frac{l^4}{l^4 + b^4}$$

See table under discussion of slabs for values of r for different values of $\frac{l}{b}$.

Bond

The question of bond is entirely eliminated in "Xpantrus" Bar design.

Where round rods are used, the following formula must be satisfied:

$$u = \frac{8}{7}\,\frac{V}{d\ \Sigma}$$

Double Reinforcement

Referring to figure 14 the following proportion must be satisfied:

$$\frac{d}{c} = \frac{y_1}{h\ y_2}$$

For all ordinary cases $y_1 + h\ y_2$ may be taken at $0.9\ (y_2 + y_1)$.

If the area of the compressive steel is less than 75% that of the tensile, sufficiently accurate results will be attained by designing

$$d = 1.75\,c$$

Columns

The ratio of unsupported length to least width should not be greater than 15. The two outside inches of a column shall be regarded as fire protection only.

In unhooped columns design for unit stress in concrete equal to 500 pounds per square inch and unit stress in longitudinal bars equal to 7,500.

In hooped columns design for unit stress in concrete within hooping equal to 1,000 pounds per square inch and unit stress in longitudinal bars equal to 15,000 pounds per square inch. The hooping must satisfy the following requirements. If r is the radius of the hooping

$\frac{r}{50}$ = area or cross section of band.

$\frac{2}{5}r$ = pitch, center to center, of bands.

$\frac{1}{5}r$ = width of band.

The proportion of steel area to effective area of concrete ranges between 1 and 2 per cent.

OBSERVATIONS ON DESIGN

While the preceding rules and formulæ, if followed conscientiously, will invariably lead the designer to safe construction, it should not be forgotten that the science of engineering design is also the science of *ECONOMIC* construction. The term economy is used here in that broad sense which condemns unsafe structures as well as those in which the material is wasted. The sense of the "fitness of things" which leads an engineer to his choice and which differentiates good engineering from bad, is acquired only by long practice accompanied by diligent thought. A hair splitting accuracy is impossible and unnecessary. This is nowhere more so than in the design of reinforced concrete structures.

An element heretofore unmentioned enters into practical design which demands serious consideration at the hands of the engineer, namely the cost of the lumber constituting the forms for the erection of the structure. When it is stated that the cost of the forms is from 30 to 50% of the cost of the concrete construction, its importance is appreciated. Hence the designer is required to take this into consideration.

The best proportion for a beam, taking the forms and the material into account, occurs when the depth is approximately twice the breadth. Hence, all other things being equal, this ratio should be maintained as closely as possible. Yet even this cannot be laid down as a hard and fast rule as will be shown when we come to speak on standardization of structures.

The width and depth of a beam should be taken such that the boards constituting the forms which encase it may be standard sizes, such as may be easily purchased in the market.

It should also be noted that the boards will be ¼ inch narrower in width, hence if the forms are tight, as they should be, an 8 inch beam becomes 7¾ inches in width and should be figured as such. The tables hereinafter given are designed for standard widths and depths, and a careful perusal should be given of the sizes adopted.

It should also be noted that in all systems, alike in the round rod loosely placed design as well as in the most complicated shop-made units, a standardization of design is very economical, hence very desirable. By this is meant that as many beams and girders as can be made so should be made alike. Where beams must perforce differ slightly in length, the same size bars as nearly as possible should be used. Where possible a uniform size should be used throughout. It should not be forgotten that a contractor's bid is based upon an estimated cost plus a reasonable percentage of profit. His estimate will be influenced by the details of the structure. Cut-up jobs will be found from 50 to 100% higher in price than standardized structures.

The "Xpantrus" System includes iron chairs for holding the bars in place before the concrete is poured. We keep a large assortment of these in stock or we are in a position to furnish them promptly, provided one of our standard sizes is selected. A complete list of those in hand will be cheerfully furnished any one so desiring. If a size not standard is desired, we can furnish them within a reasonable time. A designer should not hesitate to consult us on all questions of doubt and our engineers are at all times entirely at their service.

Numerical Example

Let it be required to design a simple T-beam where $t = 6''$, $l = 20'$, $W =$ live load uniformly distributed $= 60{,}000$ pounds, $f_s = 16{,}000$, $f_c = 750$, $n = 15$, $V_d = 50$, $V_c = 150$. Assume dead load at 34,000 pounds, hence we have $R = 47{,}000$ pounds. Assume $b = 60''$.

The effective cross section, $b'\,jd$, is governed by V_c and equals $\dfrac{47{,}000}{150} = 313$ square inches.

For the most economical proportion the depth should equal twice the breadth, which in this case will give $b' = 13\frac{1}{2}''$ and $d = 27''$. The bending moment is given by

$$M = \frac{1}{8} W l = \frac{1}{8} \times 94{,}000 \times 20 \times 12 = 2{,}820{,}000 \text{ inch pounds.}$$

The steel required is given by equation (6) or

$$A = \frac{M}{\frac{7}{8} d f_s} = \frac{2{,}820{,}000}{\frac{7}{8} \times 27 \times 16{,}000} = 7.46 \text{ square inches.}$$

The design must now satisfy the following condition:

$$f_s A < 0.45 f_c b t$$

$$16{,}000 \times 7.46 < 0.45 \times 750 \times 60 \times 6$$

$$119{,}000 < 121{,}000$$

which shows that the beam is stronger in concrete than in steel, hence the proportions $b' = 13\frac{1}{2}, d = 27$, $A = 7.46$ will be adopted.

The aggregate cross-section for vertical shear members required is given by formula (14).

$$a = 0.00104 \times 13\frac{1}{2} \times 20 \times 12 = 3.37 \text{ square inches.}$$

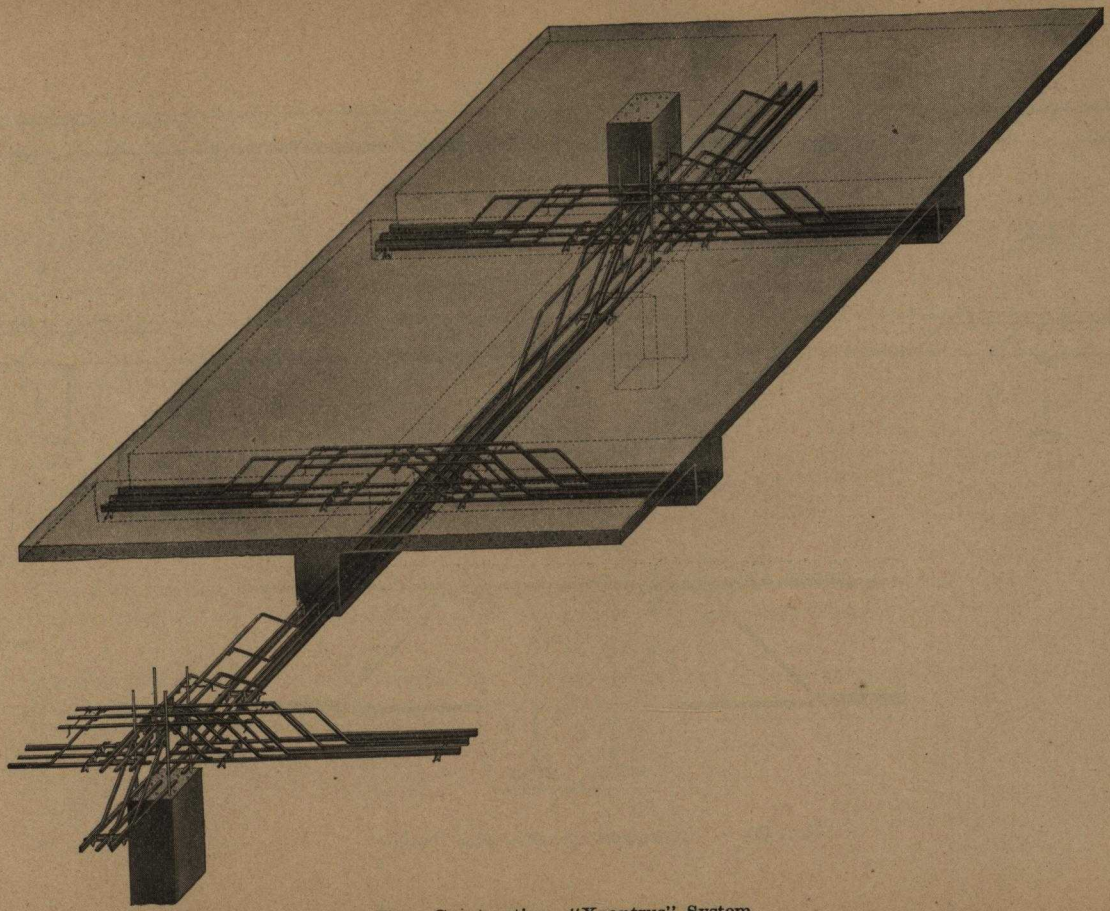
There remains yet to be ascertained the spacing and sizes of steel bars to be used. All other things being equal the fewer the bars the cheaper the handling.

If the "Xpantrus" Bar is used it will be seen that a five-bar unit will be necessary. Also that five $1\frac{1}{2}''$ bars fills the bill exactly. A glance at the table will show that the chairs required for the width adopted are standard. A rise of 24" will be required for this depth of beam.

Where round rods are selected for reinforcement, the question of bond enters into consideration. Let $u = 60$. From equation for bond.

$$\frac{8}{7} \times \frac{47{,}000}{27 \times 60} = 33 \text{ inches.}$$

Therefore it will be necessary to use 10—1" rounds or twice as many as required in the "Xpantrus" System. A little inspection will show that this steel will have to be packed in two tiers for the width of beam adopted. Where vertical stirrups only are used, they should be so placed that three-fifths of the aggregate cross section



Floor Construction—"Xpantrus" System.

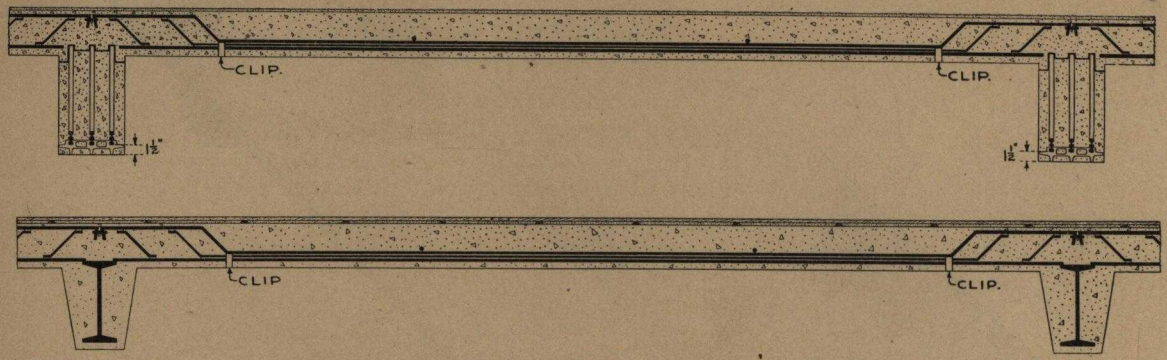


FIG. 19. The "Xpantrus" Bar as a slab reinforcement.

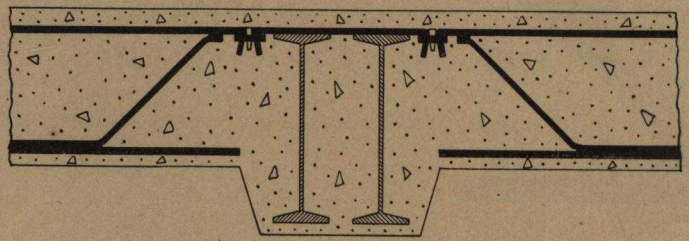


FIG. 20. "Xpantrus" Details—The "bridge."

required for web reinforcement shall be included within a distance from the support equal to the depth of the beam; one-third of the aggregate shall be included in the next depth of the beam, and the remainder near the middle third of the beam. This proportion will be found to agree closely with the distribution shown in figure 11.

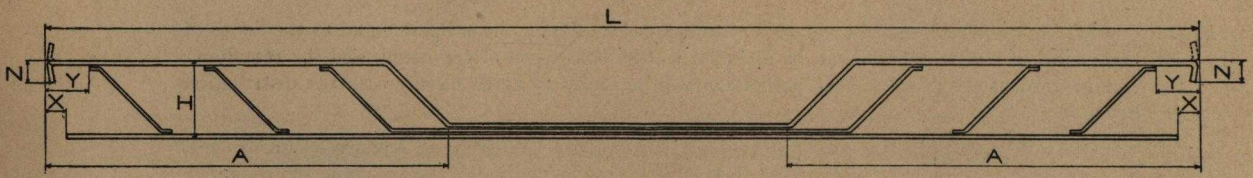
It is now possible to compare the two systems of reinforcement. Where the "Xpantrus" Bar is used, the total steel required was found to be 5—1½" Bars or a total of 520 pounds. Where loose rod reinforcement was used, 10—1" rounds were found necessary for the same work. The total weight of steel required, including the stirrups, is 590 pounds, or a saving of 13½% in steel in favor of the "Xpantrus" Bar. In a continuous beam or a girder with single load at the center, this difference would have been found still greater, amounting to from 20% to 40%.

This saving in the total quantity of steel should be taken strictly into account where the price is being considered.

It has been demonstrated repeatedly by tests on full sized beams that those which have inclined shear members anchored at both ends show a 20% greater ultimate strength than those using the loose vertical stirrups.

Added to this saving is the positiveness of the "Xpantrus" System, which is unequaled and other advantages which have been dwelt upon in the preceding pages.

XPANTRUS STANDARDS



The proportion of the length of the bar which is expanded (A) is governed by the position of the bar in the unit frame and the number of bars constituting it. Figs. 15, 17 and 18 give the maximum length of the expanded portion.

The height (H) to which the bar may be expanded is to any inch up to 36 inches. Standard rises for the various sizes of bars are elsewhere given.

The inclination of the diagonal members is 45° in all cases.

Our standard clearance for the distance given in the sketch by (X) varies from ½″ on the smaller to 2½″ on the larger sizes when the hook is down.

Distance (Y) varies from 2½″ on the smaller to 3″ on the larger sizes when the hook is down.

Distance (N) is approximately 2″ on the ½″ and ¾″ bars and 3½″ on the remaining sizes.

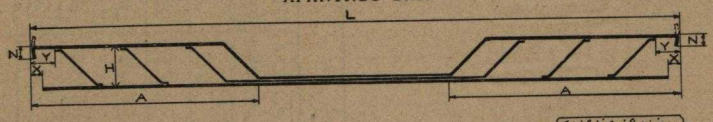
Distances (A), (H), (X), (Y) and (N) may be made to suit varying conditions and special requirements of designers. A special inquiry should be made for every variation from our standards.

When the hook is up, distances (X) and (Y) are slightly larger than when the hook is down.

THE CONSOLIDATED EXPANDED METAL COMPANIES

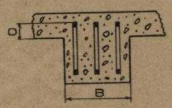
PITTSBURGH, PA.

XPANTRUS BAR



Unless otherwise noted

First Distance A and arrangement of bars in beam to be governed by our standards
Second All bars composing a beam to be assembled in shop, wired and tagged
Third Chairs, top spacers, links and wedges wired to corresponding beams
Fourth Distance N, Y and X will be governed by our standards
Fifth For data not given, see our handbook



PLEASE FILL IN THE FOLLOWING

Mark on Plan	No. of Beams	No. of Bars in each Beam	Size of Bar	Center to Center of Supports L Feet	L Inches	Expanded Height H Inches	Width of Concrete Beam B Inches	Hook Up or Down	O (Inches)	Links per Beam	Chairs per Beam Type No. 1	Chairs per Beam Type No. 2	Wire Spacers per Beam			REMARKS
	Standard assembly of bars in a beam. Sample Order.															
A_1	12	3	1½"	18	0½	16	7¾	Down	1½	3	2		2			
A_2	25	3	"	20	6	16	"	"	1½	3	3		"			
A_3	34	3	"	17	0	16	"	"	"	3	2		"			
B_1	6	3	"	19	0	16	"	"	"	3	2		"			
B_2	8	3	1	18	6	16	9¾	"	"	—	2		"			
B_3	3	5	"	18	3	16	13½	"	"	5	2		"			
B_4	2	5	"	18	6	16	"	"	"	5	2		"			
B_5	7	5	"	20	1½	16	"	"	"	5	2		"			
B_6	25	5	"	18	0	16	"	"	"	5	2		"			
C_1	14	5	"	19	1½	16	"	"	"	—	2		"			
C_2	33	7	"	20	0	16	16½	"	"	—	3		"			
C_3	1280	—	½	12	0	6	—	"	"	1000	—		—			Slab
C_4	79	—	"	11	6	6	—	"	"	60	—		—			"
C_5	63	—	"	10	6	6	—	"	"	63	—		—			"
C_6	7	3	1½	18	0	20	13½	"	"	3	3		2			
C_7	3	3	"	18	6	20	"	"	"	3	3		"			
C_8	5	3	"	19	0	20	"	Up	3	3	3		"			
	Special arrangement of bars in a beam at direction of purchasers. Sample Order.													A		
														2	pieces	EV
G_1	10	3	1	18	0	16	9¾	Down	1½	3	3		2	6	"	EVEN
														2	"	
														2	pieces	
														5	"	
G_2	13	5	1	20	0	16	9¾	"	1½	3	3			6	"	
														5	"	
														2	"	

Sample Data Sheet.

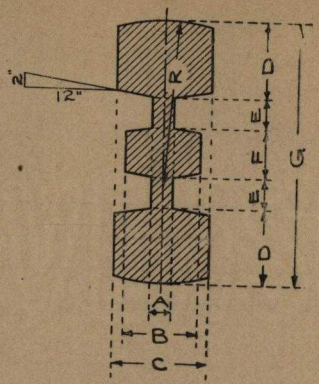
Made by A.N.O.
Checked by C.B.

Ordered by John Smith
For Park Place High School
Pittsburgh, Pa.

Customer's Order No. 1643.
Our Order No.

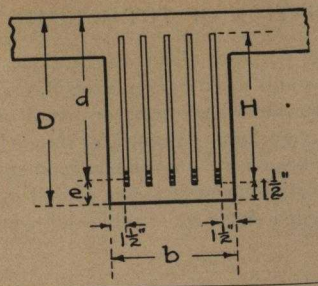
Sheet No. 1

FIG. 21. How to order "Xpantrus" Bars. Blank data sheets will be furnished on request to all interested parties.



THE "XPANTRUS" BAR.

SIZE OF BAR.	DIMENSIONS.									AREAS.				
	A	B	C	D	E	F	G	R	Perim-eters.	Webs.	Web Bar	Flange Bars.	Total Area.	Weight per ft.
1/2"	.125"	.4"	.5"	.39"	.18"	.243"	1.383"	.77"	4.84"	.045□"	.091□"	.364□"	.50□"	1.7#
3/4"	.125	.5	.7	.442	.18	.305	1.549	1.08	6.07	.045	.141	.564	.75	2.55
1"	.18	.6	.7	.555	.25	.328	1.938	1.08	6.83	.09	.182	.728	1.00	3.4
1 1/4"	.18	.6	.8	.649	.25	.411	2.209	1.233	7.73	.09	.232	.928	1.25	4.25
1 1/2"	.18	.7	.8	.774	.25	.435	2.483	1.233	8.44	.09	.282	1.128	1.50	5.1
1 3/4"	.22	.7	1.00	.697	.32	.487	2.521	1.542	9.13	.141	.321	1.287	1.75	5.95
2"	.22	.8	1.00	.80	.32	.50	2.740	1.542	9.74	.141	.372	1.487	2.00	6.8



Size of Bar	½″	¾″	1″	1¼″	1½″	1¾″	2″
Values of e	2.19	2.27	2.47	2.60	2.74	2.76	2.87

STANDARD RISES.

The rise of a bar is the expanded height including the bar itself. (Distance H– See cut on page 50.)

The "Xpantrus" bar will be furnished to any rise desired, up to 30″.

It should not be forgotten that IN ORDER TO MAKE COMMERCIALLY FEASIBLE A SHOP-FABRICATED UNIT SUCH AS THE "XPANTRUS" BAR, IT IS ESSENTIAL THAT THE CONSTRUCTION BE STANDARDIZED. THE ENGINEER OR ARCHITECT SHOULD CONFORM HIS DESIGN TO SOME SELECTED RISE FOR EACH GIVEN SIZE BAR AND USE SAME WHEREVER POSSIBLE. BY SO DOING HE CAN SECURE MINIMUM PRICES AND DELIVERIES.

STOCK.

It is our aim to carry a sufficiently large tonnage of steel in stock to meet the demands for quick shipments. Unless otherwise stated, our stock sizes will consist of ½″, 1″, and 1½″ bars. The other sizes will be furnished on request. Sufficient time will be required to obtain these sizes from the mill.

EXPLANATION OF TOTAL LOAD TABLES.

As has been previously stated, for purposes of standardization, the "Xpantrus" bar frames are recommended in combinations of three, five and seven bars to a beam. The total load beam tables are arranged according to these standards. These tables have been computed on the theory of design heretofore given They are divided into two groups, the one being designed for simple beams with a bending moment equal to $\frac{1}{8}$ *Wl* and the other for continuous beams with a bending moment equal to $\frac{1}{10}$ *Wl*. A better design may thus be obtained by proper proportioning every beam, as well as by a closer adherence to the principles involving the shear than is attainable in a single set of tables with modifying factors for the other bending moment.

The minimum thickness of slab for a given beam is given in the tables by large open number for all values within adjoining heavy lines. When the value given is 0, the beam in question is sufficiently strong in compression as a rectangular beam. The compression in the stem of the beam has been in every case taken into account.

The loadings given are the total loads uniformly distributed. The weights of the beam must be deducted to obtain the net load the beam will carry.

The spacing of the bars in adjoining beams should be made alike and the tops of the bars should be on the same elevation in order that full advantage shall be taken of the link and wedge tie which provides for continuity. This detail alone will be found to effect a great saving in the total amount of steel required in a building.

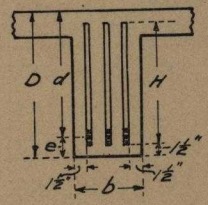
The standard expansion of the bars will provide ample reinforcement against both positive and negative bending moment as well as shear. It is only necessary to call for three, five or seven bars in a beam in the proper column of our data sheet and our standard arrangement will be given. No computations of any kind will be necessary.

The loads given are assumed as uniformly distributed. Cases will occur continually when the loads are more or less concentrated as is the case in girders. In order to take full advantage of the total load beam tables, it will be necessary to transfer these partially concentrated loads into equivalent uniform loads which will give equivalent results. This may be readily done by a designer under the principles governing common beam design. Having found this equivalent uniform load, it is merely necessary to enter the tables and proceed as before.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-½" Bar Unit Frame. Simple Beams. Steel Area = 1½ sq. in.

Span in Feet	Width b inches.	Total Depth in inches (D). 8	10	12	14	16	18	20	22	24	26	28
6	13 3/4"		18.3	22.9								
7	"	11.6	15.6	19.6	23.6							
8	"	10.1	13.7	17.2	20.7	24.2						
9	9 3/4"		12.1	15.2	18.4	21.5	24.6					
10	"		10.9	13.7	16.5	19.3	22.1	24.9				
11	7 3/4"		9.9	12.5	15.0	17.6	20.1	22.6	25.2	27.7		
12	"		9.1	11.4	13.8	16.1	18.4	20.7	23.1	25.4		
13	"			10.5	12.7	14.9	17.0	19.2	21.3	23.5	25.6	
14	"			9.8	11.8	13.8	15.8	17.8	19.8	21.8	23.8	25.8
15	"			9.1	11.0	12.9	14.8	16.6	18.5	20.4	22.2	24.1
16	"			8.6	10.3	12.1	13.8	15.6	17.3	19.1	20.8	22.6
17	"				9.7	11.4	13.0	14.7	16.3	18.0	19.5	21.2
18	"				9.2	10.7	12.3	13.9	15.4	17.0	18.5	20.1
19	"				8.7	10.2	11.6	13.1	14.6	16.1	17.5	19.1
20	"					9.7	11.1	12.5	13.9	15.3	16.6	18.1
21	"					9.2	10.6	11.9	13.2	14.5	15.8	17.2
22	"						10.1	11.3	12.6	13.9	15.1	16.4
23	"						9.6	10.8	12.1	13.3	14.4	15.7
24	"						9.2	10.4	11.6	12.8	13.8	15.0



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_S = 16{,}000\ A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.
" " " support = 100 bjd.

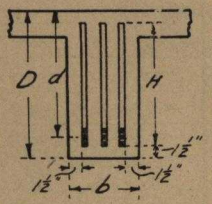
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-$\frac{3}{4}$" Bar Unit Frame. Simple Beams. Steel Area = 2.4 sq. in.

Span in Feet	Width b inches	Total Depth in inches (D). 10	12	14	16	18	20	22	24	26	28
8	15"	20.3	25.5	30.8	36.0						
9	"	18.0	22.6	27.4	32.0	36.7					
10	"	16.2	20.4	24.6	28.8	33.0	37.2				
11	11$\frac{3}{4}$"	14.7	18.5	22.4	26.2	30.0	33.8	37.7	41.5		
12	"	13.5	17.0	20.5	24.0	27.5	31.0	34.5	38.0		
13	"		15.7	18.9	22.1	25.4	28.6	31.9	35.1	38.3	
14	8$\frac{3}{4}$"		14.6	17.6	20.6	23.6	26.6	29.6	32.6	35.6	38.6
15	"		13.6	16.4	19.2	22.0	24.8	27.6	30.4	33.2	36.0
16	"		12.7	15.4	18.0	20.6	23.3	25.9	28.5	31.1	33.7
17	"			14.5	16.9	19.4	21.9	24.4	26.8	29.3	31.8
18	"			13.7	16.0	18.3	20.7	23.0	25.3	27.7	30.0
19	"			13.0	15.1	17.3	19.6	21.8	24.0	26.2	28.4
20	"				14.4	16.5	18.6	20.7	22.8	24.9	27.0
22	"				13.1	15.0	16.9	18.8	20.8	22.6	24.6
24	"					13.7	15.5	17.3	19.0	20.8	22.5
26	"						14.3	16.0	17.5	19.2	20.8
28	"							14.8	16.3	17.8	19.3



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000\, A_s\, jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear of first riser = 50 b jd.

" " " support = 100 b jd.

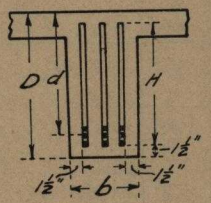
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1" Bar Unit Frame. Simple Beams. Steel Area = 3 sq. in.

Span in Feet	Width b inches	Total depth in inches (D).												
		12	14	16	18	20	22	24	26	28	30	32	34	36
12	13½	22.2	26.9	31.6	36.2	40.9	45.5	50.2						
13	"	20.5	24.8	29.1	33.4	37.8	42.0	46.4	50.8					
14	11¾	19.1	23.0	27.1	31.0	35.1	39.0	43.1	47.2	51.1	55.1			
15	"	17.8	21.5	25.3	29.0	32.7	36.4	40.2	44.0	47.7	51.4	55.1		
16	"	16.7	20.2	23.7	27.2	30.7	34.2	37.7	41.2	44.7	48.2	51.7	55.2	58.7
17	9¾		18.9	22.3	25.6	28.9	32.1	35.4	38.8	42.1	45.4	48.7	51.9	55.2
18	"		17.9	21.1	24.2	27.3	30.3	33.5	36.7	39.7	42.8	46.0	49.1	52.2
19	8¾		16.9	19.9	22.9	25.8	28.7	31.7	34.7	37.7	40.6	43.6	46.5	49.4
20	"			18.9	21.7	24.6	27.3	30.1	33.0	35.7	38.5	41.4	44.2	46.9
21	"			18.1	20.7	23.4	26.0	28.7	31.4	34.1	36.7	39.4	42.1	44.7
22	"			17.2	19.7	22.3	24.8	27.4	30.0	32.5	35.1	37.6	40.2	42.7
24	"				18.1	20.5	22.8	25.1	27.5	29.8	32.1	34.5	36.8	39.1
26	"					18.9	21.0	23.2	25.4	27.5	29.7	31.9	34.0	36.1
28	"						19.5	21.5	23.6	25.5	27.6	29.6	31.6	33.5
30	"							20.1	22.0	23.9	25.7	27.6	29.5	31.3
32	"								20.6	22.4	24.1	25.9	27.6	29.3
34	"									21.0	22.6	24.4	26.0	27.6
36	"									19.9	21.4	23.0	24.5	26.0



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000 A_s jd$

$jd = \frac{7}{8}d$ = effective depth

Max. shear at first riser = 50 bjd.

" " " support = 100 bjd.

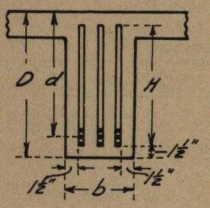
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1¼" Bar Unit Frame. Simple Beams. Steel Area = 3¾ sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 14	16	18	20	22	24	26	28	30	32	34	36.
13	15½	30.7	36.1	41.4	46.8	52.2	57.6	63.1	68.4	73.8			
14	"	28.5	33.5	38.5	43.5	48.4	53.5	58.6	63.5	68.5	73.6		
15	13½	26.6	31.3	35.9	40.6	45.2	49.9	54.6	59.3	63.9	68.6	73.3	77.9
16	"	24.9	29.3	33.7	38.1	42.4	46.8	51.2	55.6	59.9	64.3	68.7	73.1
17	11¾	23.5	27.6	31.7	35.8	39.9	44.1	48.2	52.3	56.4	60.5	64.7	68.7
18	"	22.1	26.1	29.9	33.9	37.7	41.6	45.6	49.4	53.3	57.1	61.1	64.9
19	"	21.0	24.7	28.4	32.1	35.7	39.4	43.1	46.8	50.5	54.1	57.8	61.5
20	"		23.4	26.9	30.4	33.9	37.4	40.9	44.4	47.9	51.4	54.9	58.4
21	9¾		22.3	25.7	29.0	32.3	35.7	39.0	42.3	45.7	49.0	52.3	55.6
22	"		21.3	24.5	27.7	30.8	34.1	37.3	40.4	43.6	46.8	50.0	53.1
23	"		20.4	23.5	26.5	29.5	32.6	35.7	38.7	41.7	44.8	47.8	50.8
24	"			22.5	25.4	28.3	31.2	34.2	37.1	39.9	42.8	45.8	48.7
25	"			21.6	24.4	27.1	29.9	32.8	35.6	38.4	41.1	43.9	46.7
26	"				23.5	26.1	28.8	31.5	34.2	36.9	39.5	42.3	44.9
28	"					24.2	26.7	29.3	31.7	34.3	36.8	39.3	41.8
30	"						25.0	27.3	29.7	32.0	34.3	36.7	38.9
32	"						23.4	25.6	27.8	30.0	32.2	34.3	36.5
34	"							24.1	26.1	28.2	30.3	32.3	34.4
36	"								24.7	26.7	28.6	30.5	32.5



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16000\ A_s jd$.

$jd = \frac{7}{8} d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 100 bjd.

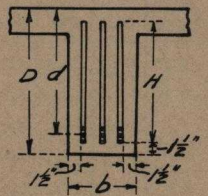
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1½" Bar Unit Frame. Simple Beams. Steel Area = 4½ sq. in.

Span in Feet	Width b inches	Total depth in inches (D).										
		16	18	20	22	24	26	28	30	32	34	36
15	17½	37.2	42.7	48.4	53.9	59.5	65.1	70.7	76.3	81.9		
16	15½	34.8	40.1	45.4	50.5	55.8	61.0	66.4	71.5	76.8	82.1	87.3
17	"	32.8	37.7	42.8	47.6	52.6	57.4	62.4	67.4	72.4	77.3	82.1
18	13½	30.9	35.6	40.4	44.9	49.6	54.2	58.9	63.5	68.3	72.9	77.5
19	"	29.3	33.8	38.3	42.6	47.0	51.4	55.9	60.2	64.8	69.1	73.5
20	"	27.9	32.1	36.3	40.4	44.7	48.8	53.1	57.2	61.5	65.7	69.7
21	11¾	26.5	30.6	34.6	38.5	42.6	46.5	50.6	54.5	58.5	62.5	66.5
22	"	25.3	29.2	33.1	36.8	40.6	44.4	48.2	52.0	55.9	59.7	63.5
23	"		27.9	31.6	35.2	38.8	42.4	46.1	49.8	53.4	57.1	60.6
24	"		26.8	30.3	33.7	37.2	40.7	44.2	47.6	51.2	54.7	58.2
25	9¾			29.1	32.4	35.7	39.1	42.4	45.8	49.2	52.5	55.8
26	"			28.0	31.1	34.4	37.6	40.8	44.0	47.4	50.4	53.6
27	"				30.0	33.1	36.2	39.3	42.4	45.5	48.6	51.7
28	"					31.9	34.9	37.9	40.8	43.9	46.9	49.8
29	"					30.8	33.7	36.6	39.5	42.4	45.3	48.2
30	"					29.8	32.5	35.4	38.1	40.9	43.7	46.6
32	"						30.5	33.2	35.7	38.4	41.1	43.6
34	"						28.7	31.2	33.7	36.2	38.6	41.1
36	"							29.5	31.8	34.1	36.5	38.7



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000\ A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd

" " " support = 100 bjd.

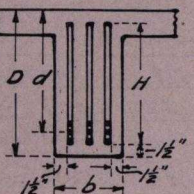
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1¾" Bar Unit Frame. Simple Beams. Steel Area = 5.4 sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 18	20	22	24	26	28	30	32	34	36	38	40
15	19½	49.8	56.3	62.8	69.4	75.9	82.4	89.0	95.5				
16	17½	46.7	52.8	58.9	65.1	71.2	77.3	83.4	89.6	95.7	101.8		
17	"	43.9	49.7	55.4	61.2	67.0	72.8	78.5	84.3	90.1	95.8	101.6	
18	"	41.5	46.9	52.4	57.8	63.2	68.7	74.2	79.6	85.1	90.4	96.0	101.2
19	15½	39.3	44.5	49.6	54.7	59.9	65.2	70.4	75.5	80.6	85.7	90.8	95.9
20	"	37.4	42.3	47.1	52.0	56.9	61.9	66.9	71.7	76.6	81.4	86.4	91.2
21	13½	35.6	40.3	44.9	49.5	54.2	58.9	63.7	68.3	72.9	77.5	82.2	86.8
22	"	33.9	38.4	42.8	47.3	51.7	56.3	60.8	65.2	69.6	74.0	78.5	82.9
23	"	32.5	36.8	40.9	45.2	49.5	53.8	58.1	62.4	66.6	70.8	75.1	79.3
24	11¾		35.2	39.3	43.3	47.4	51.6	55.6	59.8	63.8	67.8	71.9	76.0
25	"		33.9	37.7	41.6	45.5	49.4	53.4	57.3	61.3	65.1	69.1	72.9
26	"		32.5	36.2	40.0	43.8	47.6	51.4	55.2	58.9	62.6	66.4	70.2
27	"			34.9	38.5	42.1	45.8	49.5	53.1	56.7	60.4	64.0	67.5
28	"			33.6	37.1	40.6	44.2	47.7	51.2	54.6	58.1	61.6	65.2
29	"				35.9	39.3	42.6	46.1	49.4	52.8	56.1	59.6	62.8
30	"				34.7	37.9	41.2	44.6	47.8	51.1	54.2	57.6	60.8
32	"					35.5	38.7	41.8	44.8	47.8	50.8	53.9	57.0
34	"					33.5	36.4	39.3	42.2	45.0	47.8	50.7	53.6
36	"						34.3	37.1	39.8	42.5	45.2	47.9	50.7



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_S = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd

" " " support = 100 bjd.

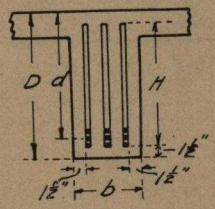
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-2" Bar Unit Frame. Simple Beams. Steel Area = 6 sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 20	22	24	26	28	30	32	34	36	38	40	42	44
17	19½	56.4	63.0	69.6	76.2	82.8	89.4	96.0	102.5	109.1	115.8			
18	"	53.3	59.5	65.7	72.0	78.2	84.5	90.7	96.9	103.1	109.1	115.5		
19	17½	50.5	56.4	62.3	68.2	74.1	80.0	85.9	91.7	97.7	103.5	109.4	115.2	
20	"	48.0	53.6	59.2	64.8	70.4	76.0	81.6	87.2	92.8	98.3	104.0	109.5	115.2
21	15½	45.7	51.0	56.3	61.7	67.1	72.4	77.8	83.0	88.4	93.7	98.9	104.2	109.8
22	"	43.6	48.7	53.8	58.9	64.0	69.1	74.2	79.2	84.4	89.4	94.5	99.6	104.8
23	"	41.7	46.6	51.4	56.3	61.2	66.1	70.9	75.8	80.8	85.4	90.4	95.3	100.2
24	13½	40.0	44.6	49.3	54.0	58.6	63.4	68.1	72.7	77.3	81.9	86.7	91.3	96.1
25	"	38.4	42.9	47.3	51.9	56.3	60.8	65.3	69.7	74.2	78.6	83.2	87.7	92.3
26	"	36.9	41.2	45.5	49.8	54.1	58.4	62.8	67.1	71.4	75.6	80.0	84.3	88.7
27	"		39.7	43.8	48.0	52.1	56.3	60.5	64.6	68.8	72.8	77.0	81.2	85.4
28	"		38.3	42.3	46.2	50.3	54.3	58.3	62.2	66.3	70.2	74.3	78.3	82.3
29	"			40.8	44.7	48.5	52.4	56.3	60.1	64.0	67.8	71.7	75.5	79.5
30	"			39.4	43.2	46.9	50.7	54.4	58.1	61.9	65.5	69.3	73.0	76.8
32	"				40.5	43.9	47.5	51.1	54.4	58.0	61.4	65.0	68.5	72.1
34	"				38.1	41.4	44.6	48.0	51.2	54.6	57.7	61.1	64.4	67.8
36	"					39.1	42.2	45.3	48.4	51.6	54.6	57.7	60.8	64.1
38	"					37.1	40.0	42.9	45.8	48.8	51.7	54.7	57.7	60.6
40	"						38.0	40.8	43.6	46.4	49.1	51.9	54.8	57.6



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000 A_s jd$.

$jd = \frac{7}{8} d$ = effective depth.

Max. shear at first riser = 50 bjd

" " " support = 100 bjd.

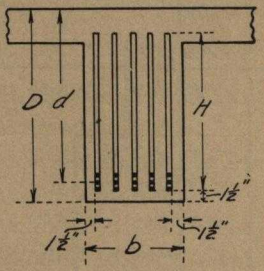
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-½" Bar Unit Frame. Simple Beams. Steel Area = 2½ sq. in.

Span in Feet.	Width b inches.	Total depth in inches (D).									
		10	12	14	16	18	20	22	24	26	28.
9	11¾	20.2	25.5	30.6							
10	"	18.2	22.9	27.6	32.2						
11	"	16.5	20.8	25.1	29.3	33.6					
12	"	15.1	19.1	23.0	26.8	30.7	34.6				
13	"		17.6	21.2	24.8	28.4	32.0	35.6	39.2		
14	"		16.4	19.7	23.0	26.4	29.7	33.1	36.4	39.7	
15	"		15.3	18.4	21.5	24.6	27.7	30.8	33.9	37.1	
16	"		14.3	17.2	20.1	23.1	25.9	28.9	31.8	34.7	37.7
17	"			16.2	18.9	21.7	24.5	27.2	29.9	32.7	35.5
18	"			15.3	17.9	20.5	23.1	25.7	28.3	30.9	33.5
19	"			14.5	16.9	19.4	21.9	24.3	26.8	29.3	31.7
20	"				16.1	18.4	20.8	23.1	25.5	27.8	30.1
21	"				15.3	17.6	19.8	22.1	24.3	26.5	28.7
22	"					16.8	18.9	21.0	23.1	25.3	27.4
23	"					16.1	18.1	20.1	22.1	24.2	26.2
24	"					15.4	17.3	19.3	21.2	23.2	25.1



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000\, A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

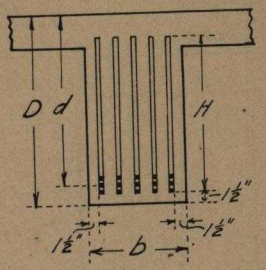
Stress in concrete = 750 #/sq. in.

Note:—
Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-$\frac{3}{4}$" Bar Unit Frame. Simple Beams. Steel Area = $3\frac{3}{4}$ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).								
		12	14	16	18	20	22	24	26	28
9	15½		45.6	53.4						
10	13½	34.0	41.0	48.0						
11	"	30.9	37.3	43.7	50.1					
12	"	28.4	34.2	40.1	45.9	51.7				
13	"	26.2	31.5	37.0	42.3	47.7	53.1	58.5		
14	"	24.3	29.3	34.3	39.3	44.3	49.3	54.3	59.3	
15	"	22.7	27.3	32.1	36.7	41.4	46.0	50.7	55.4	
16	"	21.3	25.7	30.0	34.4	38.8	43.2	47.5	51.9	56.2
17	"		24.1	28.3	32.4	36.5	40.6	44.7	48.8	52.9
18	"		22.8	26.7	30.6	34.5	38.3	42.2	46.1	50.0
19	"		21.6	25.3	29.0	32.7	36.3	40.0	43.7	47.4
20	"			24.0	27.5	31.0	34.5	38.0	41.5	45.0
22	"			21.9	25.0	28.2	31.3	34.5	37.7	40.9
24	"				22.9	25.9	28.8	31.7	34.6	37.5
26	"					23.9	26.5	29.3	31.9	34.7
28	"						24.7	27.1	29.7	32.2



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000\,Ajd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

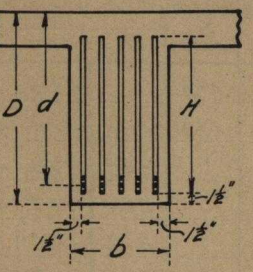
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1" Bar Unit Frame. Simple Beams. Steel Area=5 sq. in.

Span in Feet:	Width b inches	Total depth in inches (D).												
		12	14	16	18	20	22	24	26	28	30	32	34	36
13	15½		41.4	48.6	55.7	62.9	70.1	77.4						
14	13½	31.8	38.4	45.1	51.8	58.4	65.1	71.8	78.5					
15	"	29.6	35.9	42.1	48.3	54.6	60.7	67.0	73.3					
16	"	27.8	33.7	39.5	45.3	51.1	56.9	62.9	68.6	74.5	80.2			
17	"		31.7	37.1	42.6	48.1	53.6	59.1	64.6	70.2	75.5	81.1		
18	"		29.9	35.1	40.3	45.5	50.6	55.8	61.0	66.3	71.4	76.7	81.8	
19	"		28.3	33.2	38.1	43.1	47.9	52.9	57.8	62.8	67.6	72.6	77.4	82.4
20	"			31.6	36.2	40.9	45.6	50.2	54.9	59.6	64.2	68.9	73.6	78.2
21	"			30.1	34.5	38.9	43.4	47.9	52.4	56.8	61.1	65.6	70.1	74.6
22	"			28.7	32.9	37.2	41.4	45.6	49.9	54.2	58.4	62.7	66.9	71.2
24	"				30.2	34.1	37.9	41.9	45.8	49.7	53.5	57.4	61.4	65.3
26	"					31.5	35.1	38.7	42.3	45.8	49.4	53.0	56.6	60.2
28	"						32.5	35.9	39.3	42.6	45.8	49.2	52.6	55.9
30	"							33.5	36.6	39.7	42.8	45.9	49.1	52.2
32	"								34.3	37.3	40.2	43.1	46.0	48.9
34	"									35.1	37.7	40.6	43.3	46.0
36	"									33.1	35.7	38.3	40.8	43.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000 A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

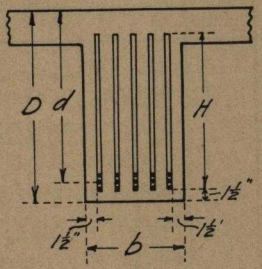
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1¼" Bar Unit Frame. Simple Beams. Steel Area = 6¼ sq. in.

Span in Feet	Width b inches	Total depth in inches (D).											
		14	16	18	20	22	24	26	28	30	32	34	36
13	18½		60.2	69.1	78.0	87.2	96.1						
14	"		55.8	64.2	72.4	80.9	89.3	97.5					
15	15½	44.3	52.1	59.9	67.8	75.4	83.3	91.0	98.8	106.6			
16	"	41.5	48.9	56.1	63.4	70.7	78.0	85.3	92.6	99.8	107.1	114.5	
17	13½	39.1	46.0	52.8	59.7	66.6	73.4	80.2	87.1	94.0	100.9	107.8	114.7
18	"	36.9	43.4	49.9	56.3	62.9	69.4	75.8	82.3	88.8	95.4	101.8	108.1
19	"	35.0	41.1	47.3	53.4	59.6	65.8	71.8	77.9	84.1	90.3	96.4	102.7
20	"		39.1	44.9	50.7	56.6	62.4	68.2	74.1	79.9	85.8	91.6	97.4
21	"		37.3	42.8	48.3	53.9	59.4	65.0	70.6	76.1	81.7	87.2	92.8
22	"		35.5	40.8	46.1	51.4	56.8	62.0	67.4	72.7	77.9	83.3	88.6
23	"		34.0	39.1	44.1	49.3	54.3	59.4	64.4	69.5	74.6	79.6	84.7
24	"			37.5	42.3	47.2	52.1	56.9	61.7	66.6	71.5	76.3	81.2
25	"			35.9	40.6	45.3	49.9	54.6	59.3	63.9	68.6	73.2	77.9
26	"				39.0	43.6	48.0	52.4	57.0	61.5	65.9	70.4	74.9
28	"					40.4	44.6	48.8	52.9	57.2	61.3	65.5	69.6
30	"						41.6	45.5	49.4	53.3	57.2	61.1	64.9
32	"						39.0	42.6	46.3	50.0	53.6	57.2	60.9
34	"							40.1	43.6	47.0	50.4	53.8	57.2
36	"								41.1	44.4	47.6	50.8	54.1



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000 A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

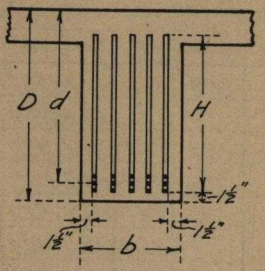
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1½" Bar Unit Frame. Simple Beams. Steel Area = 7½ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).												
		16	18	20	22	24	26	28	30	32	34	36	38	40
15	21½	61.9	71.2	80.5	89.8	99.2	108.5							
16	17½	58.0	66.8	75.5	84.3	93.0	101.8	110.4	119.2					
17	"	54.6	62.8	71.1	79.3	87.6	95.8	104.0	112.2	120.5				
18	15½	51.5	59.4	67.1	74.9	82.7	90.4	98.3	105.9	113.8	121.5	129.3		
19	"	48.9	56.3	63.6	71.0	78.4	85.7	93.1	100.3	107.8	115.2	122.5	130.0	
20	13½	46.4	53.4	60.4	67.4	74.4	81.4	88.4	95.4	102.4	109.4	116.4	123.4	
21	"	44.2	50.9	57.5	64.2	70.9	77.6	84.2	90.9	97.6	104.2	110.9	117.6	124.2
22	"	42.2	48.5	54.9	61.3	67.7	74.1	80.4	86.8	93.2	99.6	105.9	112.1	118.5
23	"		46.4	52.5	58.6	64.7	70.8	76.9	83.0	89.1	95.2	101.2	107.2	113.5
24	"		44.5	50.3	56.2	62.0	67.9	73.7	79.6	85.4	91.1	97.1	102.9	108.6
25	"			48.3	53.9	59.5	65.1	70.7	76.4	82.0	87.6	93.2	98.7	104.5
26	"			46.4	51.9	57.2	62.6	68.0	73.4	78.9	84.2	89.6	95.0	100.4
27	"				49.9	55.1	60.4	65.5	70.7	75.9	81.1	86.2	91.5	96.7
28	"				48.2	53.1	58.2	63.2	68.2	73.2	78.2	83.2	88.2	93.2
29	"					51.3	56.2	60.9	65.8	70.7	75.5	80.4	85.2	90.0
30	"					49.6	54.3	58.9	63.6	68.4	72.9	77.7	82.3	86.9
32	"						50.9	55.2	59.7	64.0	68.4	72.8	77.2	81.5
34	"						47.8	52.0	56.1	60.2	64.3	68.5	72.6	76.7
36	"							49.1	53.0	56.9	60.8	64.6	68.6	72.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000 A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

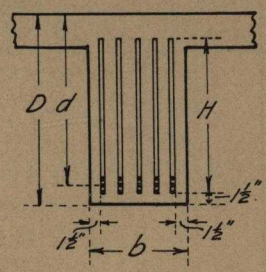
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1¾" Bar Unit Frame. Simple Beams. Steel Area = 8.74 sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 18	20	22	24	26	28	30	32	34	36	38	40
15	21½	82.9	93.7	104.7	115.6	126.4							
16	19½	77.8	87.8	98.1	108.4	118.6	128.9	139.0					
17	"	73.2	82.6	92.3	102.0	111.5	121.1	130.8	140.4				
18	17½	69.2	78.1	87.2	96.3	105.4	114.5	123.5	132.7	141.8	150.7		
19	"	65.5	74.1	82.6	91.3	99.8	108.3	117.0	125.6	134.2	142.8		
20	"	62.2	70.3	78.5	86.7	94.8	103.0	111.1	119.3	127.5	135.6		
21	15½	59.3	66.9	74.7	82.5	90.4	98.2	105.9	113.8	121.5	129.3	136.8	144.8
22	"	56.6	63.9	71.4	78.8	86.3	93.7	101.1	108.5	116.0	123.4	130.7	138.1
23	"	54.1	61.1	68.3	75.4	82.4	89.6	96.8	103.8	110.9	117.9	125.0	132.0
24	"		58.6	65.4	72.3	79.0	85.9	92.7	99.5	106.2	113.0	119.8	126.6
25	"		56.2	62.8	69.4	75.9	82.5	88.9	95.5	102.0	108.6	115.1	121.5
26	"		54.1	60.4	66.8	72.9	79.3	85.5	91.8	98.2	104.5	110.6	116.8
27	"			58.1	64.3	70.2	76.3	82.4	88.5	94.5	100.6	106.6	112.6
28	"			56.1	61.9	67.7	73.6	79.4	85.3	91.2	96.8	102.6	108.5
29	"				59.8	65.4	71.1	76.7	82.3	88.0	93.7	99.2	104.8
30	"				57.9	63.2	68.7	74.1	79.6	85.1	90.4	95.8	101.2
32	"					59.3	64.4	69.5	74.6	79.8	84.8	89.8	94.9
34	"					55.7	60.6	65.4	70.2	75.1	79.9	84.6	89.4
36	"						57.2	61.7	66.3	70.8	75.3	79.8	84.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000 A_s jd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

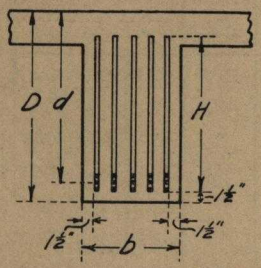
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-2" Bar Unit Frame. Simple Beams. Steel Area = 10 sq. in.

Span in Feet	Width b inches	Total depth in inches (D).												
		20	22	24	26	28	30	32	34	36	38	40	42	44
17	21½	94.1	105.1	116.2	127.0	138.1	148.9	159.9						
18	"	88.8	99.3	109.6	119.9	130.2	140.7	151.0	161.3	172.0				
19	"	84.1	94.0	103.8	113.7	123.5	133.2	143.1	152.8	162.6				
20	19½	79.9	89.4	98.6	108.0	117.3	126.5	135.9	145.1	154.6	164.0			
21	17½	76.2	85.1	93.8	102.8	111.8	120.6	129.4	138.2	147.4	156.2	164.9		
22	"	72.7	81.3	89.6	98.3	106.8	115.1	123.5	132.0	140.7	149.2	157.3	166.0	
23	15½	69.5	77.7	85.7	93.9	102.0	110.0	118.1	126.2	134.5	142.5	150.6	158.8	167.0
24	"	66.6	74.4	82.2	90.0	97.8	105.4	113.2	121.0	129.0	136.6	144.2	152.2	160.0
25	"	63.9	71.5	78.8	86.4	93.9	101.2	108.8	116.1	123.7	131.1	138.5	146.1	153.6
26	"	61.5	68.7	75.8	83.1	90.3	97.4	104.5	111.7	119.1	126.1	133.2	140.5	147.7
27	"		66.2	72.9	79.9	86.9	93.7	100.6	107.5	114.7	121.5	128.3	135.3	142.3
28	"		63.8	70.4	77.1	83.8	90.4	97.1	103.8	110.4	117.1	123.8	130.4	137.1
29	"			68.1	74.4	80.9	87.3	93.7	100.1	106.8	113.1	119.4	125.9	132.4
30	"			65.7	71.9	78.3	84.4	90.6	96.8	103.2	109.2	115.5	121.8	128.0
32	"				67.4	73.4	79.2	84.9	90.8	96.8	102.4	108.3	114.2	120.0
34	"				63.5	69.0	74.4	79.8	85.4	91.1	96.5	101.9	107.4	112.9
36	"					65.2	70.3	75.6	80.6	86.0	91.1	96.3	101.4	106.7
38	"					61.8	66.6	71.5	76.4	81.4	86.4	91.3	96.2	101.1
40	"						63.3	68.0	72.6	77.4	82.0	86.6	91.4	96.0



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000\,A_s\,jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

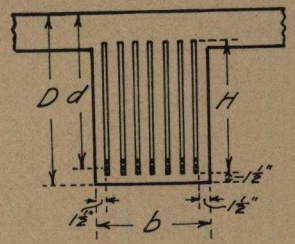
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-½" Bar Unit Frame. Simple Beams Steel Area = 3½ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).									
		10	12	14	16	18	20	22	24	26	28.
10	15½		32.1	38.6	45.1						
11	"		29.1	35.1	41.0						
12	"	21.3	26.7	32.1	37.6	43.0	48.6				
13	"	19.6	24.6	29.7	34.7	39.7	44.8	49.8			
14	"	18.2	22.9	27.6	32.2	36.9	41.6	46.2	50.9		
15	"		21.4	25.7	30.1	34.5	38.8	43.1	47.5	51.8	
16	"		20.1	24.1	28.2	32.3	36.4	40.5	44.6	48.6	52.6
17	"			22.7	26.5	30.4	34.3	38.1	41.9	45.8	49.6
18	"			21.4	25.1	28.7	32.4	35.9	39.6	43.2	46.8
19	"			20.3	23.7	27.2	30.7	34.1	37.5	40.9	44.3
20	"				22.5	25.8	29.1	32.3	35.7	38.9	42.1
21	"				21.5	24.6	27.7	30.8	33.9	37.0	40.1
22	"					23.5	26.5	29.4	32.4	35.3	38.3
23	"					22.5	25.3	28.1	31.0	33.8	36.6
24	"					21.5	24.3	27.0	29.7	32.4	35.1



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000 A_s jd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

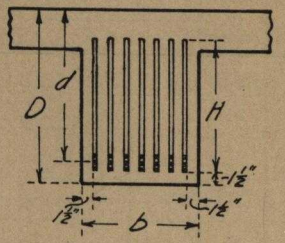
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-$\frac{3}{4}$" Bar Unit Frame. Simple Beams. Steel Area = 5$\frac{1}{4}$ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).								
		12	14	16	18	20	22	24	26	28
11	18$\frac{1}{2}$			61.2	70.1					
12	16$\frac{1}{2}$		47.9	56.1	64.3					
13	"		44.3	51.8	59.3	66.9				
14	"	34.1	41.1	48.1	55.1	62.1	69.1	76.1		
15	"	31.8	38.3	44.9	51.4	57.9	64.4	71.0	77.5	
16	"	29.9	35.9	42.1	48.2	54.3	60.4	66.5	72.7	
17	"		33.8	39.6	45.3	51.1	56.9	62.6	68.4	74.2
18	"		31.9	37.4	42.8	48.3	53.7	59.1	64.6	70.1
19	"		30.3	35.4	40.6	45.7	50.9	56.1	61.2	66.3
20	"			33.7	38.5	43.4	48.3	53.2	58.2	63.1
22	"			30.6	35.0	39.5	43.9	48.4	52.9	57.3
24	"				32.1	36.2	40.3	44.4	48.4	52.5
26	"					33.4	37.1	40.9	44.7	48.5
28	"						34.5	38.0	41.5	45.0



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 b jd

" " " support = 150 b jd.

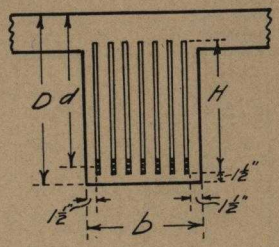
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1"Bar Unit Frame. Simple Beams. Steel Area = 7 sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 14	16	18	20	22	24	26	28	30	32	34	36
13	19½			78.0	88.1								
14	"		63.2	72.4	81.8	91.2	100.4						
15	"		59.0	67.6	76.3	85.0	93.8						
16	16½	47.1	55.3	63.4	71.6	79.8	87.9	96.1					
17	"	44.3	52.1	59.6	67.4	75.0	82.7	90.4	98.1	105.8			
18	"	41.8	49.2	56.3	63.6	70.9	78.1	85.4	92.7	99.9	107.2		
19	"	39.6	46.6	53.4	60.3	67.1	74.0	80.9	87.8	94.7	101.6		
20	"		44.2	50.7	57.3	63.8	70.3	76.9	83.4	89.9	96.4	103.0	109.5
21	"		42.1	48.2	54.6	60.7	66.9	73.2	79.4	85.7	91.8	98.1	104.3
22	"		40.2	46.1	52.1	58.0	63.9	69.9	75.8	81.8	87.7	93.7	99.5
24	"			42.2	47.7	53.2	58.6	64.1	69.5	74.9	80.4	85.9	91.3
26	"				44.1	49.1	54.1	59.1	64.2	69.2	74.2	79.2	84.2
28	"					45.6	50.2	54.9	59.6	64.2	68.9	73.6	78.2
30	"						46.9	51.3	55.6	59.9	64.4	68.7	73.0
32	"							48.1	52.2	56.2	60.3	64.4	68.5
34	"								49.1	52.9	56.7	60.6	64.4
36	"								46.4	50.0	53.6	57.2	60.9



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_s = 16{,}000\,A\,jd.$

$jd = \frac{7}{8}d$ = effective depth

Max. shear at first riser = 50 b j d

" " " support = 150 b j d.

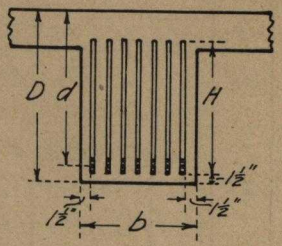
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1¼" Bar Unit Frame. Simple Beams. Steel Area = 8¾ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).										
		16	18	20	22	24	26	28	30	32	34	36.
14	24½			101.4	113.2	124.9						
15	21½		83.8	94.8	105.6	116.5	127.3					
16	19½		78.5	88.9	99.1	109.2	119.3	129.8	139.8			
17	"	64.4	73.9	83.6	93.3	102.8	112.4	122.1	131.5	141.2		
18	17½	60.9	69.8	79.0	88.1	97.0	106.2	115.2	124.2	133.3		
19	"	57.7	66.1	74.8	83.4	91.9	100.6	109.2	117.8	126.3	135.0	143.7
20	"	54.8	62.9	71.1	79.3	87.4	95.5	103.8	111.9	120.0	128.2	136.4
21	"	52.2	59.9	67.7	75.5	83.2	91.0	98.8	106.6	114.3	122.1	129.9
22	"	49.8	57.1	64.7	72.1	79.4	86.9	94.4	101.8	109.1	116.7	124.0
23	"	47.6	54.6	61.9	68.9	75.9	83.1	90.2	97.3	104.3	111.4	118.7
24	"	7	52.4	59.3	66.1	72.8	79.7	86.5	93.2	99.9	106.9	113.7
25	"		50.3	56.9	63.4	69.9	76.4	82.9	89.4	96.0	102.6	109.1
26	"		6	54.7	60.9	67.2	73.5	79.8	86.0	92.3	98.7	104.9
28	"				56.6	62.4	68.3	74.2	79.9	85.7	91.6	97.4
30	"					58.3	63.8	69.2	74.6	80.0	85.4	90.9
32	"					54.6	59.8	64.8	69.9	75.1	80.1	85.3
34	"						56.2	61.1	65.8	70.6	75.4	80.3
36	"							57.6	62.2	66.7	71.3	75.8



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000\, A\, jd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

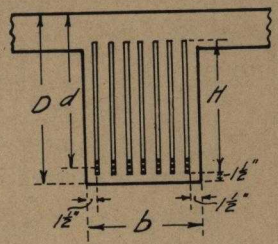
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1½" Bar Unit Frame. — Simple Beams. — Steel Area = 10½ sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 18	20	22	24	26	28	30	32	34	36	38	40
15	25			125.9	139.0	152.0							
16	23½		105.8	118.1	130.3	142.5							
17	"		99.5	111.1	122.8	134.1	145.5	157.1					
18	21½	83.2	94.0	104.9	115.9	126.7	137.5	148.3	159.2				
19	"	78.8	89.0	99.4	109.8	120.0	130.1	140.5	151.0				
20	19½	74.8	84.6	94.4	104.2	114.0	123.8	133.6	143.4	153.2	163.0		
21	18½	71.3	80.6	89.9	99.3	108.7	117.8	127.1	136.7	145.8	155.2	164.5	
22	"	68.0	76.9	85.8	94.8	103.6	112.3	121.5	130.4	139.2	148.1	157.0	166.0
23	"	65.1	73.6	82.2	90.7	99.2	107.5	116.1	124.8	133.3	141.8	150.1	158.8
24	"	62.4	70.5	78.7	86.9	95.0	103.1	111.3	119.6	127.6	135.8	143.9	152.1
25	"		67.7	75.5	83.4	91.2	98.9	106.8	114.8	122.5	130.3	138.1	146.0
26	"		65.1	72.7	80.2	87.7	95.2	102.8	110.3	117.7	125.3	132.9	140.4
27	"			70.0	77.3	84.4	91.6	98.9	106.2	113.4	120.8	128.0	135.2
28	"			67.5	74.5	81.4	88.3	95.4	102.4	109.3	116.3	123.3	130.4
29	"				71.9	78.7	85.3	92.2	98.9	105.7	112.3	119.1	125.9
30	"				69.5	76.0	82.4	89.1	95.7	102.1	108.6	115.2	121.8
32	"					71.3	77.3	83.4	89.6	95.8	101.8	107.9	114.1
34	"					67.1	72.7	78.6	84.4	90.2	95.8	101.6	107.4
36	"						68.7	74.2	79.7	85.2	90.5	95.9	101.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{8}$ $M_s = 16{,}000\ A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 b j d.

" " " support = 150 b j d.

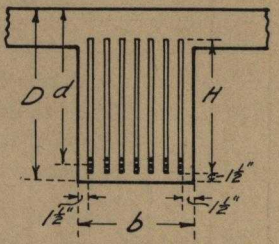
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1¾" Bar Unit Frame. Simple Beams. Steel Area = 12¼ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).										
		20	22	24	26	28	30	32	34	36	38	40
16	27½			151.6	166.0							
17	"		129.4	142.9	156.3	169.8	183.3					
18	24½		122.2	134.9	147.6	160.3	173.1	185.8				
19	"	103.8	115.8	127.9	139.7	151.9	163.9	176.0				
20	"	98.5	110.0	121.4	132.8	144.2	155.7	167.2	178.7	190.0		
21	21½	93.8	104.8	115.8	126.5	137.5	148.5	159.1	170.1	180.8	191.9	
22	"	89.6	100.0	110.3	120.9	131.1	141.8	152.0	162.4	172.7	183.2	193.5
23	19½	85.7	95.6	105.5	115.4	125.5	135.4	145.3	155.3	165.3	175.2	185.1
24	"	82.1	91.6	101.2	110.8	120.2	129.7	139.4	148.9	158.4	167.9	177.4
25	"	78.8	88.0	97.2	106.3	115.5	124.6	133.8	142.9	151.9	161.2	170.3
26	"	75.8	84.6	93.4	102.2	111.0	119.9	128.7	137.3	146.2	155.0	163.8
27	"		81.5	89.9	98.4	106.9	115.4	123.9	132.2	140.8	149.2	157.6
28	"		78.6	86.7	94.9	103.1	111.3	119.4	127.6	135.8	143.9	152.1
29	"			83.8	91.7	99.5	107.4	115.3	123.2	131.0	139.0	146.8
30	"			80.9	88.7	96.3	103.9	111.5	119.0	126.7	134.3	141.9
32	"				83.1	90.3	97.4	104.5	111.7	118.8	126.0	133.1
34	"				78.2	84.8	91.6	98.4	105.1	111.8	118.5	125.2
36	"					80.2	86.6	92.9	99.3	105.5	112.0	118.3



Stress in steel = 16,000 #/sq. in

$M = \frac{Wl}{8}$ $M_s = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

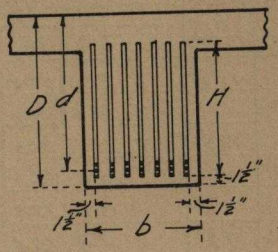
Stress in concrete = 750 #/sq. in

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-2" Bar Unit Frame. Simple Beams. Steel Area = 1.45 sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 20	22	24	26	28	30	32	34	36	38	40	42
17	31½				177.8	193.4	208.5						
18	28½			153.5	167.9	182.5	196.9	211.4					
19	"		131.6	145.5	159.1	173.0	186.7	200.5	214.2				
20	26		125.1	138.2	151.1	164.0	177.2	190.3	203.2	216.5			
21	24	106.8	119.1	131.4	144.0	156.5	168.8	181.4	193.8	206.2	218.7		
22	"	101.8	113.8	125.6	137.3	149.5	161.1	173.0	185.1	196.8	208.9	220.9	
23	"	97.4	108.8	120.2	131.3	143.0	154.0	165.5	177.0	188.1	199.7	211.0	
24	21½	93.4	104.2	115.1	126.0	137.0	147.7	158.7	169.6	180.4	191.3	202.2	213.0
25	"	89.6	100.1	110.6	121.0	131.6	141.8	152.2	162.8	173.0	183.6	194.3	204.6
26	19½		96.3	106.2	116.2	126.5	136.3	146.5	156.5	166.4	176.8	186.8	196.8
27	"		92.7	102.4	112.0	121.8	131.3	141.0	150.8	160.2	170.2	180.0	189.5
28	"		89.3	98.7	108.0	117.4	126.7	136.0	145.4	154.7	164.1	173.4	182.6
29	"			95.4	104.2	113.4	122.3	131.3	140.3	149.3	158.4	167.3	176.4
30	"			92.2	100.8	109.4	118.2	126.8	135.8	144.3	153.2	161.9	170.5
32	"				94.5	102.8	110.8	119.0	127.3	135.2	143.6	151.8	159.8
34	"				88.9	96.7	104.2	111.9	119.8	127.3	135.1	142.9	150.4
36	"					91.4	98.4	105.7	113.2	120.2	127.4	135.0	142.1
38	"					86.6	93.3	100.1	107.1	113.9	120.9	127.8	134.6
40	"						88.6	95.2	101.8	108.1	114.9	121.4	127.8



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{8}$ $M_S = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd

" " " support = 150 bjd.

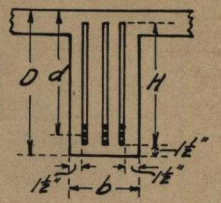
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-½" Bar Unit Frame — Continuous Beams. — Steel Area = 1½ Sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 8	10	12	14	16	18	20	22	24	26	28
6	17½		22.8	28.6								
7	"	14.5	19.5	24.5	29.5							
8	13½	12.7	17.1	21.5	25.8	30.2						
9	"		15.2	19.1	23.0	26.9	30.8					
10	"		13.6	17.2	20.7	24.2	27.7	31.2				
11	9¾		12.4	15.6	18.8	22.0	25.2	28.3	31.5	34.7		
12	"		11.4	14.3	17.2	20.1	23.1	26.0	28.9	31.8		
13	7¾			13.2	15.9	18.6	21.3	24.0	26.7	29.4	32.1	
14	"			12.3	14.7	17.3	19.8	22.3	24.8	27.3	29.8	32.3
15	"			11.4	13.8	16.1	18.4	20.8	23.1	25.4	27.8	30.1
16	"			10.7	12.9	15.1	17.3	19.5	21.7	23.9	26.0	28.2
17	"				12.2	14.2	16.3	18.3	20.4	22.4	24.5	26.6
18	"				11.5	13.4	15.4	17.3	19.3	21.2	23.2	25.1
19	"				10.9	12.7	14.6	16.4	18.2	20.1	21.9	23.8
20	"					12.1	13.8	15.6	17.3	19.0	20.8	22.6
21	"					11.5	13.2	14.8	16.5	18.2	19.8	21.5
22	"						12.6	14.2	15.8	17.3	18.9	20.5
23	"						12.0	13.5	15.1	16.6	18.1	19.6
24	"						11.5	13.0	14.4	15.9	17.4	18.8



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\, A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 100 bjd.

Stress in concrete = 750 #/sq. in.

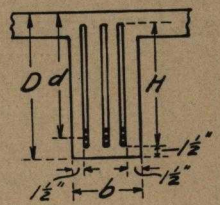
Note:—

Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-$\frac{3}{4}$" Bar Unit Frame. Continuous Beams. Steel Area = 2$\frac{1}{4}$ sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 10	12	14	16	18	20	22	24	26	28
8	19$\frac{1}{2}$	25.4	31.9	38.5	45.1						
9	"	22.5	28.4	34.2	40.1	45.9					
10	15$\frac{1}{2}$	20.3	25.5	30.8	36.0	41.3	46.5				
11	"	18.4	23.2	28.0	32.8	37.5	42.3	47.1	51.9		
12	"	16.9	21.3	25.7	30.0	34.4	38.8	43.2	47.6		
13	11$\frac{3}{4}$		19.6	23.7	27.7	31.8	35.8	39.8	43.9	47.9	
14	"		18.2	22.0	25.7	29.5	33.2	37.0	40.8	44.5	48.3
15	"		17.0	20.5	24.0	27.5	31.0	34.5	38.0	41.5	45.0
16	"		16.0	19.2	22.5	25.8	29.1	32.4	35.7	38.9	42.2
17	"			18.1	21.2	24.3	27.4	30.5	33.6	36.6	39.7
18	8$\frac{3}{4}$			17.1	20.0	22.9	25.9	28.8	31.7	34.6	37.5
19	"			16.2	19.0	21.7	24.5	27.2	30.0	32.8	35.5
20	"				18.2	20.6	23.3	25.9	28.5	31.2	33.8
22	"				16.4	18.8	21.2	23.5	25.9	28.3	30.7
24	"					17.2	19.4	21.6	23.8	26.0	28.1
26	"						17.9	19.9	22.0	24.0	26.0
28	"							18.5	20.4	22.3	24.1



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\ A\,j\,d$.

$jd = \frac{7}{8}d$ = effective depth.

Max. sheor at first riser = 50 bjd.

" " " support = 100 bjd.

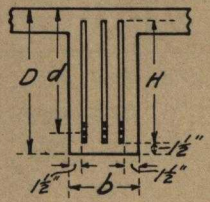
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1" Bar Unit Frame. Continuous Beams. Steel Area = 3 sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).												
		12	14	16	18	20	22	24	26	28	30	32	34	36
12	17½	27.8	33.6	39.5	45.3	51.1	57.0	62.8						
13	15½	25.6	31.0	36.4	41.8	47.2	52.6	58.0	63.3					
14	"	23.8	28.8	33.8	38.8	43.8	48.8	53.8	58.8	63.8	68.8			
15	13½	22.2	26.9	31.6	36.2	40.9	45.6	50.2	54.9	59.6	64.2	68.9		
16	"	20.8	25.2	29.6	34.0	38.4	42.7	47.1	51.5	55.9	60.3	64.6	69.0	73.3
17	11¾		23.7	27.9	32.0	36.1	40.2	44.3	48.4	52.6	56.7	60.8	64.9	69.0
18	"		22.4	26.3	30.2	34.1	38.0	41.9	45.7	49.6	53.5	57.4	61.3	65.2
19	"		21.2	24.9	28.6	32.3	36.0	39.7	43.3	47.0	50.7	54.4	58.1	61.8
20	"			23.7	27.2	30.7	34.2	37.7	41.2	44.7	48.2	51.7	55.2	58.7
21	9¾			22.6	25.9	29.2	32.5	35.9	39.2	42.5	45.9	49.2	52.5	55.9
22	"			21.5	24.7	27.9	31.1	34.3	37.4	40.6	43.8	47.0	50.1	53.4
24	8¾				22.6	25.6	28.5	31.4	34.3	37.2	40.2	43.1	46.0	48.9
26	"					23.6	26.3	29.0	31.7	34.4	37.1	39.8	42.4	45.2
28	"						24.4	26.9	29.4	31.9	34.4	36.9	39.4	41.9
30	"							25.1	27.4	29.8	32.1	34.5	36.8	39.1
32	"								25.7	27.9	30.1	32.3	34.5	36.7
34	"									26.3	28.3	30.4	32.5	34.5
36	"									24.8	26.8	28.7	30.7	32.6



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\ A_s jd$.

$jd = \frac{7}{8} d$ = effective depth.

Max. shear at first riser = 50 bjd

" " " support = 100 bjd.

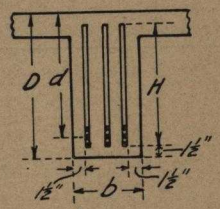
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1¼" Bar Unit Frame. Continuous Beams. Steel Area = 3¾ sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 14	16	18	20	22	24	26	28	30	32	34	36
13	19½	38.4	45.1	51.8	58.6	65.3	72.0	78.8	85.5	92.2			
14	"	35.6	41.9	48.1	54.4	60.6	66.9	73.1	79.4	85.6	91.9		
15	17½	33.3	39.1	44.9	50.7	56.6	62.4	68.2	74.1	79.9	85.7	91.6	97.4
16	"	31.2	36.6	42.1	47.6	53.0	58.5	64.0	69.5	74.9	80.4	85.8	91.3
17	15½	29.4	34.5	39.6	44.8	49.9	55.1	60.2	65.4	70.5	75.6	80.8	86.0
18	"	27.7	32.6	37.4	42.3	47.2	52.0	56.9	61.8	66.6	71.4	76.3	81.2
19	13½	26.2	30.9	35.5	40.1	44.7	49.3	53.9	58.5	63.1	67.7	72.3	76.9
20	"		29.3	33.7	38.1	42.4	46.8	51.2	55.6	60.0	64.3	68.7	73.1
21	"		27.9	32.1	36.3	40.4	44.6	48.8	52.9	57.1	61.2	65.4	69.6
22	11¾		26.7	30.6	34.6	38.6	42.6	46.5	50.5	54.5	58.5	62.5	66.4
23	"		25.5	29.3	33.1	36.9	40.7	44.5	48.3	52.1	55.9	59.7	63.5
24	"			28.1	31.7	35.4	39.0	42.7	46.3	49.9	53.6	57.2	60.9
25	"			27.0	30.5	33.9	37.4	41.0	44.5	48.0	51.5	55.0	58.4
26	9¾				29.3	32.6	36.0	39.4	42.6	46.1	49.5	52.8	56.2
28	"					30.3	33.4	36.6	39.7	42.8	46.0	49.1	52.2
30	"						31.2	34.1	37.0	40.0	42.8	45.8	48.7
32	"						29.3	32.0	34.7	37.5	40.2	42.9	45.7
34	"							30.2	32.7	35.3	37.8	40.4	43.0
36	"								30.9	33.3	35.7	38.2	40.6



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000 A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 100 bjd.

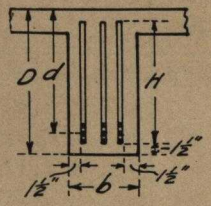
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1½" Bar Unit Frame. Continuous Beams. Steel Area = 4½ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).										
		16	18	20	22	24	26	28	30	32	34	36.
15	20	46.4	53.4	60.4	67.4	74.4	81.4	88.4	95.4	102.4		
16	"	43.5	50.1	56.6	63.2	69.8	76.3	82.9	89.4	96.0	102.6	109.1
17	"	41.0	47.1	53.3	59.5	65.7	71.8	78.0	84.2	90.4	96.6	102.7
18	17½	38.7	44.5	50.4	56.2	62.0	67.9	73.7	79.5	85.4	91.2	97.0
19	"	36.6	42.2	47.7	53.2	58.7	64.3	69.8	75.3	80.9	86.4	91.9
20	15½	34.8	40.1	45.3	50.6	55.8	61.0	66.3	71.6	76.8	82.1	87.3
21	"	33.2	38.2	43.2	48.2	53.1	58.1	63.1	68.1	73.2	78.2	83.2
22	"	31.6	36.4	41.2	46.0	50.7	55.5	60.3	65.0	69.9	74.8	79.4
23	13½	4	34.8	39.4	44.0	48.5	53.1	57.6	62.2	66.8	71.3	75.9
24	"		33.4	37.8	42.2	46.5	50.9	55.3	59.6	64.0	68.4	72.8
25	"			36.3	40.5	44.7	48.8	53.1	57.2	61.4	65.6	69.9
26	11¾			34.9	38.9	42.9	47.0	51.0	55.1	59.1	63.1	67.2
27	"				37.5	41.3	45.2	49.1	53.0	56.9	60.8	64.7
28	"					39.9	43.6	47.4	51.1	54.9	58.6	62.4
29	"					38.5	42.1	45.7	49.4	53.0	56.6	60.2
30	"					37.2	40.7	44.2	47.7	51.2	54.7	58.2
32	9¾						38.2	41.4	44.7	48.0	51.3	54.6
34	"						35.9	39.0	42.1	45.2	48.3	51.3
36	"							36.8	39.7	42.7	45.6	48.5



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.
" " " support = 100 bjd.

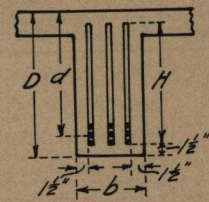
Stress in concrete = 750 #/sq. in.

Note:—
Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-1 3/4" Bar Unit Frame. Continuous Beams. Steel Area = 5 1/4 sq. in.

Span in Feet.	Width b inches.	Total depth in inches (D).											
		18	20	22	24	26	28	30	32	34	36	38	40
15	23 1/2	62.2	70.4	78.6	86.7	94.9	103.1	111.3	119.4				
16	"	58.3	66.0	73.6	81.3	89.0	96.6	104.1	111.9	119.6	127.3		
17	"	54.9	62.1	69.3	76.5	83.7	90.9	98.1	105.4	112.6	119.8	126.9	
18	19 1/2	51.9	58.7	65.5	72.3	79.1	85.9	92.7	99.5	106.3	113.1	119.9	126.7
19	"	49.1	55.6	62.0	68.5	74.9	81.4	87.8	94.3	100.7	107.2	113.6	120.0
20	17 1/2	46.7	52.8	58.9	65.1	71.2	77.3	83.4	89.5	95.7	101.8	107.9	114.0
21	"	44.4	50.3	56.1	62.0	67.8	73.6	79.5	85.3	91.1	97.0	102.7	108.6
22	"	42.4	48.0	53.6	59.2	64.7	70.3	75.9	81.4	87.0	92.6	98.1	103.6
23	15 1/2	40.6	45.9	51.2	56.6	61.9	67.2	72.6	77.9	83.2	88.5	93.9	99.2
24	"		44.0	49.1	54.2	59.3	64.4	69.5	74.6	79.7	84.8	89.9	95.0
25	"		42.2	47.1	52.1	56.9	61.9	66.7	71.7	76.6	81.5	86.3	91.3
26	13 1/2		40.6	45.3	50.1	54.8	59.5	64.2	68.9	73.6	78.3	83.1	87.7
27	"			43.6	48.2	52.8	57.3	61.8	66.3	70.9	75.4	79.9	84.5
28	"			42.1	46.5	50.9	55.2	59.6	64.0	68.4	72.7	77.1	81.5
29	"				44.9	49.1	53.3	57.6	61.8	66.0	70.1	74.5	78.7
30	11 3/4				43.4	47.4	51.5	55.7	59.9	63.8	67.9	71.9	76.1
32	"					44.5	48.3	52.1	56.0	59.8	63.6	67.5	71.3
34	"					41.9	45.5	49.1	52.7	56.3	59.9	63.5	67.1
36	"						43.0	46.4	49.8	53.2	56.6	59.9	63.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000 A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 100 bjd.

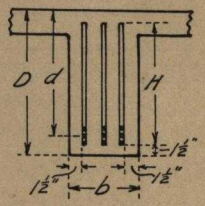
Stress in concrete = 750 #/sq. in

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

3-2" Bar Unit Frame. Continuous Beams. Steel Area = 6 sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).												
		20	22	24	26	28	30	32	34	36	38	40	42	44
17	23½	70.5	78.8	87.0	95.2	103.4	111.6	119.9	128.1	136.4	144.6			
18	"	66.6	74.4	82.2	90.0	97.7	105.5	113.3	121.0	128.8	136.6	144.4		
19	21½	63.1	70.5	77.9	85.2	92.6	100.0	107.3	114.7	122.0	129.4	136.8	144.1	
20	"	59.9	66.9	74.0	81.0	88.0	95.0	101.9	108.9	115.9	123.0	130.0	136.9	144.0
21	19½	57.1	63.7	70.4	77.1	83.8	90.4	97.1	103.7	110.4	117.1	123.8	130.4	137.1
22	"	54.5	60.8	67.2	73.6	80.0	86.3	92.7	99.0	105.4	111.8	118.1	124.5	130.8
23	17½	52.1	58.2	64.3	70.4	76.5	82.6	88.7	94.8	100.8	106.9	113.1	119.1	125.2
24	"	49.9	55.8	61.6	67.5	73.3	79.2	85.0	90.8	96.6	102.5	108.4	114.1	120.0
25	"	48.0	53.5	59.2	64.8	70.4	76.0	81.6	87.2	92.8	98.5	104.0	109.6	115.2
26	15½	46.1	51.5	56.9	62.3	67.7	73.0	78.4	83.8	89.2	94.7	100.0	105.3	110.8
27	"		49.6	54.8	60.0	65.2	70.3	75.5	80.7	85.9	91.1	96.3	101.4	106.6
28	"		47.8	52.8	57.8	62.8	67.8	72.8	77.8	82.8	87.9	92.9	97.8	102.8
29	"			51.0	55.8	60.7	65.5	70.3	75.1	80.0	84.9	89.7	94.5	99.3
30	13½			49.3	54.0	58.7	63.3	68.0	72.6	77.3	82.0	86.7	91.3	96.0
32	"				50.6	55.0	59.3	63.7	68.1	72.5	76.9	81.3	85.8	90.0
34	"				47.6	51.8	55.9	60.0	64.1	68.2	72.3	76.5	80.6	84.7
36	"					48.9	52.7	56.7	60.5	64.4	68.3	72.3	76.1	80.0
38	"					46.3	50.0	53.7	57.4	61.0	64.7	68.4	72.1	75.8
40	"						47.5	51.0	54.5	58.0	61.5	65.0	68.5	72.0



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\ A_s\ jd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 b jd.

" " " support = 100 b jd.

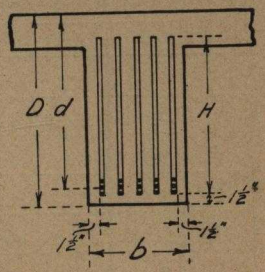
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-½" Bar Unit Frame. Continuous Beams. Steel Area = 2½ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).									
		10	12	14	16	18	20	22	24	26	28.
9	13½	25.3	31.8	38.2							
10	11¾	22.8	28.6	34.4	40.3						
11	"	20.7	26.0	31.3	36.6	41.9					
12	"	19.0	23.8	28.7	33.5	38.4	43.3				
13	"		22.0	26.5	31.0	35.5	39.9	44.4	48.9		
14	"		20.4	24.6	28.8	32.9	37.1	41.3	45.4	49.6	
15	"		19.1	23.0	26.8	30.7	34.6	38.5	42.4	46.3	
16	"		17.9	21.5	25.2	28.8	32.4	36.1	39.8	43.4	47.1
17	"			20.3	23.7	27.1	30.5	34.0	37.4	40.8	44.3
18	"			19.1	22.4	25.6	28.8	32.1	35.3	38.6	41.8
19	"			18.1	21.2	24.3	27.3	30.4	33.5	36.5	39.6
20	"				20.2	23.0	25.9	28.9	31.8	34.7	37.6
21	"				19.2	21.9	24.7	27.5	30.3	33.1	35.9
22	"					21.0	23.6	26.3	28.9	31.5	34.2
23	"					20.0	22.6	25.1	27.7	30.2	32.7
24	"					19.2	21.6	24.1	26.5	28.9	31.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\ Ajd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

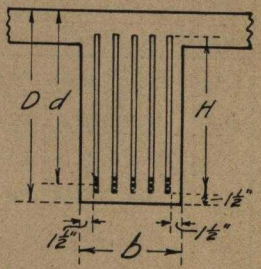
Stress in concrete = 750 #/sq. in.

Note.— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-$\frac{3}{4}$" Bar Unit Frame. Continuous Beams. Steel Area = $3\frac{3}{4}$ sq. in.

Span in Feet	Width b inches	Total depth in inches (D).								
		12	14	16	18	20	22	24	26	28.
9	$19\frac{1}{2}$		57.0	66.8						
10	"	42.6	51.3	60.1						
11	$15\frac{1}{2}$	387	46.7	54.7	62.5					
12	"	35.5	42.8	50.1	57.3	64.7				
13	$13\frac{1}{2}$	32.8	39.4	46.2	52.9	59.7	66.4	73.1		
14	"	30.4	36.6	42.9	49.1	55.4	61.7	67.9	74.1	
15	"	28.4	34.2	40.0	45.9	51.7	57.5	63.4	69.2	
16	"	26.6	32.1	37.5	43.0	48.5	53.9	59.4	64.9	70.4
17	"		30.2	35.3	40.5	45.6	50.8	55.9	61.1	66.3
18	"		28.5	33.4	38.2	43.1	47.9	52.8	57.7	62.5
19	"		27.0	31.6	36.2	40.8	45.4	50.0	54.6	59.3
20	"			30.1	34.4	38.8	43.1	47.5	51.9	56.3
22	"			27.4	31.3	35.3	39.2	43.2	47.2	51.2
24	"				28.7	32.3	35.9	39.6	43.3	46.9
26	"					29.8	33.2	36.6	39.9	43.3
28	"						30.8	34.0	37.1	40.2



Stress in steel = 16,000 #/sq. in

$M = \frac{WL}{10}$ $M_s = 16{,}000\ A_s\ jd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

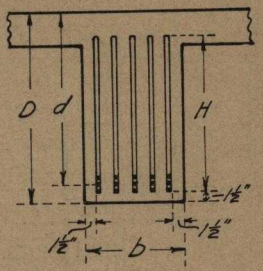
Stress in concrete = 750 #/sq. in

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1" Bar Unit Frame. Continuous Beams. Steel Area = 5 sq. in.

Span in Feet.	Width b, inches	Total depth in inches (D).												
		12	14	16	18	20	22	24	26	28	30	32	34	36
13	17½		51.7	60.7	69.7	78.7	87.6	96.5						
14	"	39.8	48.0	56.3	64.7	73.1	81.3	89.7	98.1					
15	15½	37.1	44.8	52.6	60.4	68.2	75.9	83.7	91.5					
16	"	34.8	42.0	49.3	56.6	63.9	71.1	78.5	85.8	93.1	100.4			
17	13½		39.5	46.4	53.3	60.2	67.0	73.8	80.8	87.6	94.5	101.3		
18	"		37.3	43.8	50.3	56.8	63.3	69.7	76.3	82.8	89.3	95.7	102.2	
19	"		35.4	41.5	47.7	53.8	59.9	66.1	72.3	78.4	84.6	90.7	96.8	102.9
20	"			39.4	45.3	51.1	56.9	62.8	68.6	74.5	80.3	86.1	92.0	97.9
21	"			37.6	43.1	48.7	54.2	59.8	65.4	70.9	76.5	82.0	87.6	93.2
22	"			35.9	41.2	46.5	51.7	57.1	62.4	67.7	73.1	78.3	83.7	89.0
24	"				37.7	42.6	47.5	52.3	57.2	62.1	66.9	71.8	76.7	81.5
26	"					39.3	43.8	48.3	52.8	57.3	61.8	66.3	70.8	75.3
28	"						40.7	44.8	49.0	53.2	57.4	61.5	65.7	69.9
30	"							41.9	45.8	49.7	53.6	57.5	61.3	65.2
32	"								42.9	46.6	50.3	53.8	57.5	61.2
34	"									43.8	47.3	50.7	54.1	57.6
36	"									41.4	44.7	47.9	51.1	54.4



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth

Max. shear at first riser = $50\,bjd$.

" " " support = $150\,bjd$.

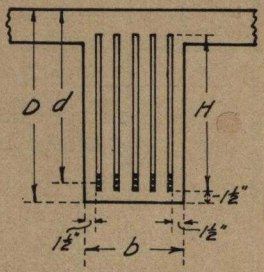
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1¼" Bar Unit Frame. Continuous Beams. Steel Area = 6¼ sq. in.

Span in Feet	Width b inches	Total depth in inches (D).											
		14	16	18	20	22	24	26	28	30	32	34	36.
13	21½		75.1	86.4	97.7	108.8	120.0						
14	"		69.8	80.3	90.7	101.1	111.4	121.8					
15	18½	55.4	65.1	74.9	84.6	94.3	104.0	113.7	123.5	133.2			
16	"	51.9	61.0	70.2	79.3	88.5	97.5	106.6	115.7	124.9	134.0	143.1	
17	"	48.9	57.5	66.1	74.7	83.2	91.8	100.4	108.9	117.6	126.1	134.6	143.3
18	15½	46.2	54.3	62.4	70.5	78.6	86.7	94.8	102.9	111.1	119.1	127.1	135.4
19	"	43.7	51.4	59.1	66.8	74.5	82.1	89.8	97.5	105.1	112.8	120.5	128.2
20	"	6	48.8	56.1	63.5	70.7	78.0	85.3	92.7	99.9	107.2	114.4	121.8
21	13½		46.5	53.5	60.5	67.3	74.3	81.3	88.2	95.2	102.1	109.0	116.0
22	"		44.4	51.1	57.7	64.3	70.9	77.6	84.2	90.9	97.5	104.1	110.7
23	"		42.5	48.8	55.2	61.5	67.8	74.2	80.5	86.9	93.3	99.5	105.9
24	"			46.8	52.9	58.9	65.0	71.1	77.2	83.3	89.3	95.4	101.5
25	"			45.0	50.8	56.6	62.4	68.3	74.1	79.9	85.8	91.6	97.5
26	"			5	48.8	54.4	60.0	65.6	71.3	76.9	82.5	88.1	93.7
28	"					50.5	55.7	60.9	66.1	71.4	76.6	81.8	87.0
30	"						52.0	56.9	61.7	66.7	71.5	76.3	81.2
32	"						48.8	53.3	57.9	62.5	67.0	71.5	76.1
34	"							50.2	54.5	58.8	63.1	67.3	71.7
36	"								51.5	55.5	59.6	63.6	67.7



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\,A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

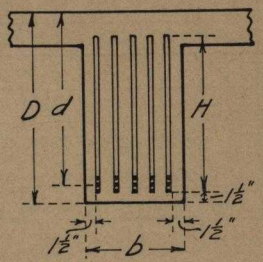
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1½" Bar Unit Frame. Continuous Beams. Steel Area = 7½ sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 16	18	20	22	24	26	28	30	32	34	36	38	40
15	23½	77.3	89.0	100.7	112.3	124.0	135.7							
16	21½	72.5	83.5	94.5	105.3	116.2	127.2	138.1	149.1					
17	"	68.2	78.5	88.9	99.1	109.4	119.7	130.0	140.3	150.6				
18	"	64.4	74.2	83.9	93.6	103.3	113.1	122.8	132.5	142.3	151.9	161.7		
19	17½	61.0	70.3	79.5	88.7	97.9	107.1	116.4	125.5	134.8	143.9	153.1	162.4	
20	"	58.0	66.7	75.5	84.2	93.0	101.8	110.5	119.2	128.1	136.7	145.5	154.2	
21	"	55.2	63.6	71.9	80.2	88.6	96.9	105.2	113.6	121.9	130.3	138.6	146.9	155.2
22	15½	52.7	60.7	68.7	76.6	84.6	92.5	100.4	108.4	116.4	124.4	132.3	140.2	148.2
23	"		58.1	65.7	73.3	80.9	88.5	96.1	103.6	111.4	118.9	126.6	134.1	141.7
24	"		55.6	62.9	70.2	77.5	84.8	92.1	99.4	106.7	113.9	121.2	128.5	135.8
25	13½			60.5	67.4	74.4	81.5	88.4	95.4	102.4	109.4	116.4	123.4	130.4
26	"			58.1	64.8	71.5	78.3	85.0	91.7	98.5	105.2	111.9	118.6	125.3
27	"				62.4	68.9	75.4	81.9	88.3	94.9	101.4	107.7	114.3	120.7
28	"				60.2	66.4	72.7	78.9	85.2	91.5	97.7	103.9	110.2	116.4
29	"					64.1	70.2	76.2	82.3	88.3	94.3	100.4	106.4	112.4
30	"					62.0	67.9	73.7	79.5	85.4	91.2	97.0	102.8	108.6
32	"						63.6	69.1	74.5	80.1	85.5	90.9	96.4	101.8
34	"						59.9	65.0	70.1	75.4	80.5	85.6	90.8	95.9
36	"							61.4	66.3	71.2	76.0	80.9	85.7	90.6



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

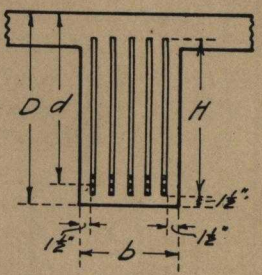
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-1¾" Bar Unit Frame. Continuous Beams. Steel Area = 8¾ sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 18	20	22	24	26	28	30	32	34	36	38	40
15	26		117.3	130.9	144.6	158.2							
16	24½	97.3	110.0	122.7	135.6	148.3	161.1	173.8					
17	"	91.5	103.5	115.5	127.6	139.6	151.6	163.6	175.6				
18	"	86.5	97.7	109.1	120.5	131.8	143.2	154.5	165.9	177.1	188.6		
19	21½	81.9	92.7	103.4	114.2	124.9	135.6	146.4	157.1	167.8	178.6	189.3	
20	19½	77.8	88.0	98.2	108.4	118.6	128.9	139.1	149.2	159.4	169.7	179.8	
21	"	74.1	83.8	93.5	103.3	113.1	122.8	132.5	142.1	151.8	161.6	171.3	181.1
22	"	70.7	80.0	89.3	98.7	107.9	117.2	126.4	135.6	144.9	154.3	163.5	172.8
23	17½	67.7	76.5	85.4	94.3	103.2	112.1	120.9	129.8	138.6	147.6	156.4	165.2
24	"		73.3	81.9	90.4	98.9	107.4	115.9	124.4	132.9	141.4	149.8	158.4
25	"		70.4	78.6	86.8	95.0	103.1	111.3	119.4	127.6	135.8	143.9	152.1
26	15½		67.7	75.6	83.5	91.3	99.2	106.9	114.8	122.6	130.6	138.3	146.2
27	"			72.7	80.4	87.9	95.5	103.0	110.5	118.1	125.8	133.2	140.8
28	"			70.1	77.5	84.8	92.1	99.3	106.6	113.8	121.2	128.4	135.8
29	"				74.8	81.9	88.9	95.9	102.9	109.9	117.1	124.1	131.1
30	"				72.3	79.1	85.9	92.7	99.5	106.3	113.1	119.8	126.7
32	"					74.2	80.5	86.9	93.3	99.7	106.1	112.4	118.8
34	"					69.8	75.8	81.8	87.8	93.8	99.9	105.8	111.8
36	"						71.6	77.3	82.9	88.6	94.3	99.9	105.6



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\,A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd

" " " support = 150 bjd.

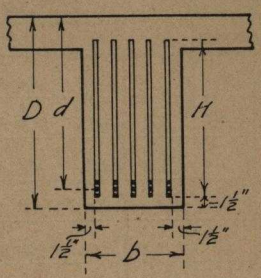
Stress in concrete = 750 #/sq. in.

Note:— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

5-2" Bar Unit Frame. Continuous Beams. Steel Area = 10 sq. in.

Span in Feet	Width b inches	Total depth in inches (D). 20	22	24	26	28	30	32	34	36	38	40	42
17	26½	117.5	131.4	145.1	158.7	172.4	186.3	200.0					
18	"	110.9	124.1	137.0	149.9	162.9	175.9	188.9	201.7	214.8			
19	23½	105.2	117.5	129.8	142.0	154.3	166.6	178.9	191.1	203.4	215.8		
20	"	99.9	111.6	123.3	134.9	146.6	158.3	170.0	181.6	193.3	204.9		
21	21½	95.1	106.4	117.4	128.5	139.6	150.8	161.9	172.9	184.1	195.1	206.2	
22	"	90.8	101.5	112.1	122.6	133.4	143.9	154.5	165.1	175.7	186.3	196.8	207.4
23	19½	86.9	97.1	107.3	117.3	127.5	137.6	147.8	157.8	168.1	178.2	188.3	198.5
24	"	83.3	93.1	102.8	112.4	122.1	131.9	141.6	151.3	161.1	170.7	180.4	190.2
25	"	79.9	89.3	98.7	107.9	117.3	126.6	136.0	145.3	154.6	163.9	173.3	182.5
26	17½	76.9	85.9	94.9	103.8	112.7	121.8	130.8	139.7	148.7	157.6	166.6	175.5
27	"		82.7	91.3	99.9	108.6	117.3	125.8	134.5	143.2	151.8	160.4	169.1
28	"		79.7	88.1	96.4	104.7	113.1	121.4	129.6	138.1	146.4	154.7	163.0
29	15½			85.1	93.1	101.1	109.2	117.2	125.2	133.3	141.4	149.4	157.4
30	"			82.2	89.9	97.7	105.6	113.3	121.1	128.8	136.6	144.4	152.1
32	"				84.3	91.7	99.0	106.2	113.5	120.7	128.1	135.4	142.6
34	"				79.3	86.3	93.1	99.9	106.8	113.6	120.6	127.4	134.2
36	"					81.5	87.9	94.5	100.8	107.4	113.8	120.3	126.8
38	"					77.1	83.3	89.5	95.5	101.7	107.8	114.0	120.2
40	"						79.2	85.1	90.8	96.7	102.4	108.3	114.1



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\,A_s\,jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 b j d.

" " " support = 150 b j d.

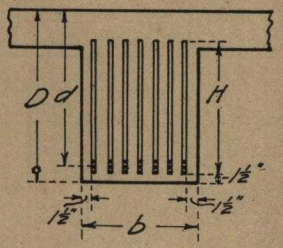
Stress in concrete = 750 #/sq. in.

Note.— Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-½" Bar Unit Frame — Continuous Beams. — Steel Area = 3½ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).									
		10	12	14	16	18	20	22	24	26	28.
10	19½		40.1	48.2	56.4						
11	15½		36.4	43.9	51.3						
12	"	26.6	33.4	40.2	47.0	53.8	60.6				
13	"	24.5	30.8	37.1	43.4	49.7	56.0	62.2			
14	"	22.8	28.6	34.5	40.3	46.2	51.9	57.8	63.6		
15	"		26.7	32.1	37.7	43.1	48.5	53.9	59.4	64.7	
16	"		25.1	30.1	35.3	40.4	45.5	50.6	55.7	60.8	65.8
17	"			28.4	33.2	38.0	42.8	47.6	52.4	57.2	62.0
18	"			26.8	31.4	35.9	40.4	44.9	49.5	54.0	58.5
19	"			25.4	29.7	34.0	38.3	42.6	46.9	51.1	55.4
20	"				28.2	32.3	36.4	40.4	44.6	48.6	52.6
21	"				26.9	30.8	34.7	38.5	42.4	46.3	50.1
22	"					29.4	33.1	36.7	40.5	44.1	47.9
23	"					28.1	31.7	35.1	38.7	42.3	45.8
24	"					26.9	30.3	33.7	37.1	40.5	43.9



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\ A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

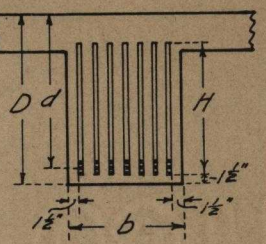
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams

7-$\frac{3}{4}$" Bar Unit Frame. Continuous Beams. Steel Area = 5$\frac{1}{4}$ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).								
		12	14	16	18	20	22	24	26	28.
11	22$\frac{1}{2}$			76.5	87.6					
12	"		59.9	70.1	80.3					
13	18$\frac{1}{2}$		55.3	64.8	74.1	83.6				
14	"	42.6	51.4	60.1	68.8	77.6	86.4	95.1		
15	16$\frac{1}{2}$	39.8	47.9	56.1	64.2	72.4	80.5	88.8	96.9	
16	"	37.3	44.9	52.6	60.2	67.9	75.5	83.1	90.9	
17	"		42.3	49.5	56.6	63.9	71.1	78.2	85.5	92.8
18	"		39.9	46.7	53.5	60.4	67.2	73.9	80.7	87.7
19	"		37.9	44.3	50.7	57.2	63.6	70.1	76.5	82.9
20	"			42.1	48.1	54.3	60.4	66.5	72.7	78.9
22	"			38.3	43.8	49.4	54.9	60.5	66.1	71.7
24	"				40.2	45.2	50.3	55.5	60.5	65.7
26	"					41.8	46.4	51.2	55.8	60.6
28	"						43.2	47.5	51.9	56.3



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\ A_s jd$.

$jd = \frac{7}{8}d$ = effective depth

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

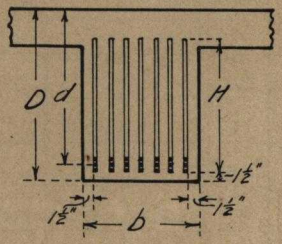
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1"Bar Unit Frame. Continuous Beams. Steel Area = 7 sq. in.

Span in Feet	Width b inches	Total depth in inches (D).											
		14	16	18	20	22	24	26	28	30	32	34	36.
13	26½			97.5	110.1								
14	23½		79.0	90.6	102.2	113.9	125.6						
15	"		73.7	84.5	95.4	106.3	117.2	128.1					
16	19½	58.8	69.1	79.3	89.5	99.7	109.9	120.1					
17	"	55.4	65.1	74.6	84.2	93.8	103.4	113.1	122.6	132.3			
18	"	52.3	61.5	70.5	79.5	88.6	97.7	106.7	115.8	124.9	134.0		
19	16½	49.6	58.2	66.8	75.3	83.9	92.6	101.1	109.7	118.4	127.0		
20	"		55.3	63.4	71.5	79.7	87.9	96.1	104.2	112.4	120.6	128.7	136.9
21	"		52.7	60.3	68.2	75.9	83.8	91.5	99.3	107.1	114.9	122.6	130.4
22	"		50.3	57.7	65.1	72.5	79.9	87.3	94.8	102.2	109.6	117.1	124.4
24	"			52.9	59.7	66.4	73.3	80.1	86.9	93.7	100.6	107.3	114.1
26	"				55.1	61.3	67.7	73.9	80.2	86.5	92.8	99.1	105.3
28	"					56.9	62.8	68.6	74.5	80.3	86.2	91.9	97.8
30	"						58.7	64.1	69.5	75.0	80.5	85.9	91.3
32	"							60.1	65.2	70.3	75.4	80.5	85.6
34	"								61.3	66.1	71.0	75.7	80.5
36	"								57.9	62.5	67.1	71.5	76.1



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\,A_s jd$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

Stress in concrete = 750 #/sq. in.

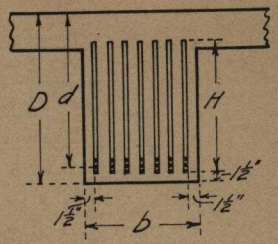
Note:-

Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1¼" Bar Unit Frame. Continuous Beams. Steel Area = 8 3/4 sq. in.

Span in Feet.	Width b inches.	Total depth in inches (D). 16	18	20	22	24	26	28	30	32	34	36.
14	28			126.8	141.4	156.0						
15	"		104.7	118.4	132.1	145.6	159.3					
16	24½		98.3	110.9	123.8	136.5	149.4	162.2	174.8			
17	"	80.5	92.5	104.4	116.4	128.4	140.5	152.5	164.6	176.5		
18	"	76.0	87.3	98.7	110.0	121.3	132.7	143.9	155.4	166.7		
19	21½	72.0	82.7	93.5	104.2	114.9	125.7	136.4	147.2	157.9	168.7	179.4
20	19½	68.4	78.6	88.8	99.0	109.2	119.4	129.6	139.9	150.1	160.3	170.5
21	"	65.1	74.9	84.5	94.3	104.0	113.7	123.4	133.3	142.9	152.7	162.3
22	"	62.2	71.5	80.7	90.0	99.3	108.6	117.8	127.2	136.4	145.7	155.0
23	17½		68.3	77.2	86.1	94.9	103.9	112.6	121.6	130.5	139.4	148.2
24	"		65.5	74.0	82.5	91.0	99.5	107.9	116.6	125.1	133.6	142.1
25	"		62.9	71.1	79.2	87.3	95.5	103.6	111.9	120.1	128.3	136.4
26	"			68.3	76.2	84.0	91.9	99.7	107.6	115.4	123.4	131.1
28	"				70.7	78.0	85.4	92.6	99.9	107.2	114.5	121.8
30	"					72.8	79.7	86.4	93.3	100.1	106.8	113.6
32	"					68.2	74.7	81.0	87.5	93.8	100.2	106.6
34	"						70.3	76.3	82.3	88.3	94.3	100.3
36	"							72.0	77.7	83.4	89.1	94.7



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16{,}000\,A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

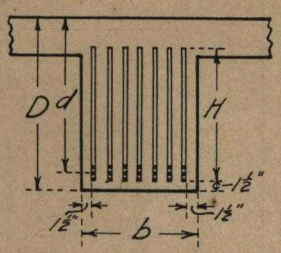
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1½" Bar Unit Frame. Continuous Beams. Steel Area = 10½ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D).											
		18	20	22	24	26	28	30	32	34	36	38	40
15	31			157.4	173.7	189.9							
16	"		132.2	147.5	162.8	178.0							
17	27½		124.2	138.8	153.3	167.5	182.0	196.4					
18	"	103.9	117.3	131.1	144.8	158.2	171.9	185.4					
19	25	98.3	111.1	124.2	137.1	149.8	162.8	175.7	188.6				
20	23½	93.7	105.6	118.0	130.2	142.4	154.6	166.9	179.1	191.4	203.7		
21	"	89.1	100.6	112.4	124.1	135.6	147.3	159.0	170.6	182.3	193.8	205.8	
22	21½	84.9	96.0	107.3	118.4	129.5	140.6	151.7	162.8	174.0	185.1	196.4	207.4
23	"	81.4	91.9	102.6	113.3	123.8	134.5	145.1	155.8	166.4	177.2	187.8	198.4
24	19½	77.8	88.0	98.3	108.6	118.6	128.8	139.1	149.2	159.5	169.6	179.9	190.1
25	"		84.5	94.4	104.2	113.7	123.7	133.6	143.3	153.1	162.8	172.7	182.6
26	18½		81.3	90.8	100.2	109.6	119.0	128.4	137.8	147.2	156.6	166.2	175.5
27	"			87.5	96.5	105.5	114.6	123.6	132.7	141.8	150.8	160.0	169.0
28	"			84.3	93.1	101.7	110.5	119.2	127.9	136.6	145.4	154.3	163.1
29	"				89.9	98.2	106.6	115.1	123.5	132.0	140.4	149.0	157.4
30	"				86.9	94.9	103.1	111.3	119.4	127.6	135.8	144.0	152.1
32	"					89.0	96.7	104.4	111.9	119.6	127.2	134.9	142.6
34	"					83.8	91.0	98.2	105.4	112.6	119.7	127.0	134.3
36	"						85.9	92.7	99.5	106.4	113.1	119.9	126.8



Stress in steel = 16,000 #/sq. in.

$M = \frac{WL}{10}$ $M_s = 16,000 A_s jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 b/d.

" " " support = 150 b/d.

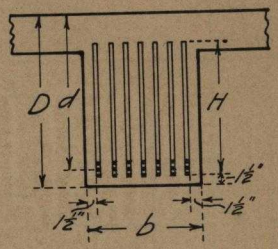
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-1¾" Bar Unit Frame. Continuous Beams. Steel Area = 12¼ sq. in.

Span in Feet.	Width b inches	Total depth in inches (D). 18	20	22	24	26	28	30	32	34	36	38	40
16	34				189.6	207.5							
17	"			161.7	178.5	195.3	212.1	229.0					
18	30½			152.7	168.6	184.5	200.2	216.1	232.1				
19	"		129.6	144.6	159.7	174.7	189.7	204.9	219.9				
20	27½		123.2	137.4	151.7	166.0	180.3	194.6	208.9	223.2	237.5		
21	"	103.8	117.4	130.9	144.6	158.1	171.7	185.4	198.9	212.9	226.2		
22	"	99.1	112.1	124.9	138.0	150.9	163.8	176.9	189.9	203.1	216.0		
23	24½		107.1	119.5	131.9	144.3	156.8	169.3	181.6	194.4	206.7	219.0	231.2
24	"		102.7	114.5	126.4	138.4	150.3	162.2	174.1	186.2	198.0	209.8	221.7
25	"		98.7	109.9	121.4	132.8	144.3	155.7	167.1	178.6	190.0	201.5	212.8
26	21½		94.8	105.7	116.7	127.7	138.7	149.7	160.7	171.7	182.8	193.6	204.7
27	"			101.8	112.4	123.0	133.6	144.1	154.7	165.3	176.0	186.5	197.0
28	19½			98.2	108.4	118.6	128.8	139.1	149.2	159.6	169.8	179.7	190.0
29	"				104.6	114.4	124.4	134.2	144.1	154.1	163.9	173.5	183.4
30	"				101.2	110.6	120.2	129.7	139.2	148.8	158.4	167.8	177.3
32	"					103.7	112.6	121.6	130.5	139.6	148.5	157.3	166.2
34	"					97.7	106.1	114.5	122.9	131.4	139.8	148.1	156.4
36	"						100.2	108.1	116.1	124.1	132.0	139.8	147.7



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\,A_s\,jd$.

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

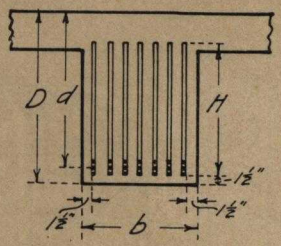
Stress in concrete = 750 #/sq. in.

Note:- Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Safe total load in thousands of pounds uniformly distributed for concrete T beams.

7-2"Bar Unit Frame. Continuous Beams. Steel Area = 14 sq. in.

Span in Feet	Width b inches	Total depth in inches (D).											
		20	22	24	26	28	30	32	34	36	38	40	42
17	37				222.2	241.8	260.8						
18	"			191.7	210.0	228.1	246.1	264.3					
19	34½			181.6	198.9	216.1	233.1	250.6	267.8				
20	"		156.2	172.6	188.9	205.0	221.6	237.9	254.2				
21	31½	133.3	148.8	164.3	180.0	195.6	211.0	226.8	242.2	257.8	273.2		
22	28½	127.2	142.1	157.0	171.8	186.7	201.5	216.2	231.2	246.0	261.0	275.9	
23	"	121.6	135.9	150.1	164.4	178.6	192.6	206.9	221.2	235.1	249.6	263.9	
24	26	116.6	130.2	143.8	157.5	171.1	184.6	198.4	211.9	225.5	239.1	252.8	266.3
25	"	111.9	125.0	138.1	151.2	164.3	177.3	190.4	203.5	216.4	229.7	242.8	255.8
26	24		120.2	132.8	145.4	158.0	170.4	183.1	195.6	208.1	220.8	233.3	245.9
27	"		115.7	127.8	140.0	152.1	164.1	176.3	188.4	200.3	212.7	224.8	236.8
28	"		111.6	123.3	135.0	146.7	158.3	170.0	181.6	193.3	205.0	216.8	228.3
29	21½			119.0	130.4	141.6	152.8	164.2	175.4	186.6	197.8	209.1	220.4
30	"			115.1	126.0	136.8	147.7	158.6	169.6	180.4	191.4	202.2	213.1
32	19½				118.1	128.4	138.5	148.7	159.0	169.1	179.3	189.6	199.7
34	"				111.1	120.8	130.4	140.0	149.6	159.1	168.8	178.4	188.1
36	"					114.1	123.1	132.2	141.3	150.4	159.4	168.5	177.6
38	"					108.1	116.6	125.3	133.8	142.4	151.0	159.6	168.2
40	"						110.8	119.0	127.2	135.3	143.4	151.6	159.8



Stress in steel = 16,000 #/sq. in.

$M = \frac{Wl}{10}$ $M_s = 16{,}000\ A_s jd.$

$jd = \frac{7}{8}d$ = effective depth.

Max. shear at first riser = 50 bjd.

" " " support = 150 bjd.

Stress in concrete = 750 #/sq. in.

Note:-
Minimum thickness of slab for values within adjoining heavy lines given by large open numbers.

Cubic Feet of Concrete per Lineal Foot of Rectangular Beams and Columns.

Size Inches.	4"	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36"
8"	.22	.33	.44														
10	.28	.42	.56	.70													
12	.33	.50	.67	.83	1.00												
14	.39	.58	.78	.97	1.17	1.36											
16	.44	.67	.89	1.11	1.33	1.56	1.78										
18	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25									
20	.56	.83	1.11	1.39	1.67	1.95	2.22	2.50	2.78								
22	.61	.92	1.22	1.53	1.83	2.14	2.44	2.75	3.05	3.36							
24	.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00						
26	.72	1.08	1.44	1.81	2.17	2.53	2.89	3.25	3.61	3.97	4.33	4.70					
28	.78	1.17	1.56	1.94	2.33	2.72	3.11	3.50	3.89	4.28	4.67	5.06	5.45				
30	.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25			
32	.89	1.33	1.78	2.22	2.67	3.11	3.56	4.00	4.45	4.89	5.33	5.78	6.22	6.67	7.11		
34	.94	1.42	1.89	2.36	2.83	3.30	3.78	4.25	4.73	5.20	5.67	6.14	6.61	7.08	7.56	8.03	
36	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00
38	1.06	1.58	2.11	2.64	3.17	3.70	4.22	4.75	5.28	5.81	6.33	6.86	7.39	7.91	8.44	8.97	9.50
40	1.11	1.67	2.22	2.78	3.33	3.89	4.44	5.00	5.56	6.12	6.67	7.22	7.78	8.34	8.89	9.44	10.00
42	1.17	1.75	2.33	2.92	3.50	4.09	4.67	5.25	5.83	6.42	7.00	7.59	8.17	8.75	9.33	9.91	10.50
44	1.22	1.83	2.44	3.06	3.67	4.28	4.89	5.50	6.11	6.72	7.33	7.95	8.56	9.17	9.78	10.39	11.00
46	1.28	1.92	2.56	3.20	3.83	4.47	5.11	5.75	6.39	7.03	7.67	8.31	8.95	9.58	10.22	10.85	11.50
48	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00	8.67	9.33	10.00	10.67	11.33	12.00
50"	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.25	6.94	7.64	8.33	9.03	9.72	10.42	11.11	11.80	12.50

Weight of Concrete in Pounds per Lineal Foot of Rectangular Beams and Columns.

Size Inches.	4"	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36"
8"	33	50	66														
10	42	63	84	105													
12	50	75	101	126	150												
14	59	87	117	147	174	204											
16	66	101	132	168	201	234	264										
18	75	113	150	189	225	273	300	338									
20	84	125	168	210	249	293	336	375	420								
22	92	138	183	228	276	321	366	413	456	504							
24	101	150	201	249	300	335	402	450	498	551	600						
26	108	162	216	270	324	380	432	488	540	596	648	705					
28	117	176	234	291	351	408	468	525	582	642	702	759	816				
30	125	188	249	312	375	438	498	563	624	687	750	813	876	938			
32	134	200	267	333	399	467	534	600	666	734	798	867	933	1001	1068		
34	141	213	282	354	426	495	564	638	708	780	852	921	990	1062	1128	1205	
36	150	225	300	375	450	525	600	675	750	825	900	975	1050	1125	1200	1275	1350
38	159	237	318	396	474	555	636	713	792	872	948	1029	1110	1187	1272	1346	1425
40	167	251	333	417	501	584	666	750	834	918	1002	1083	1167	1251	1332	1416	1500
42	176	263	351	438	525	614	702	788	876	963	1050	1139	1227	1313	1404	1487	1575
44	183	275	366	458	549	642	732	825	918	1008	1098	1193	1284	1376	1464	1559	1650
46	192	288	384	480	576	671	768	863	960	1055	1152	1247	1341	1437	1536	1628	1725
48	200	300	399	501	600	701	798	900	1002	1100	1200	1301	1401	1500	1596	1700	1800
50"	209	312	417	522	624	729	834	938	1044	1146	1248	1355	1458	1563	1668	1770	1875

MIXTURE.			MATERIAL FOR 1 CUBIC YARD RAMMED CONCRETE.								
			STONE. 1 inch and under. dust screened out.			STONE. 2½ inch and under. dust screened out.			GRAVEL. ¾ inch and under.		
Cement	Sand.	Stone or Gravel.	Cement. bbls.	Sand cu. yds.	Stone cu. yds.	Cement bbls.	Sand cu. yds.	Stone cu. yds.	Cement bbls.	Sand. cu yds.	Gravel. cu. yds.
1	1	2	2.57	0.39	0.78	2.63	0.40	0.80	2.30	0.35	0.74
1	1	3	2.06	0.31	0.94	2.10	0.32	0.96	1.89	0.29	0.86
1	1½	3	1.85	0.42	0.84	1.90	0.43	0.87	1.71	0.39	0.78
1	1½	4	1.57	0.36	0.96	1.61	0.37	0.98	1.46	0.33	0.88
1	2	3	1.70	0.52	0.77	1.73	0.53	0.79	1.54	0.47	0.73
1	2	4	1.46	0.44	0.89	1.48	0.45	0.90	1.34	0.41	0.81
1	2	5	1.27	0.39	0.97	1.29	0.39	0.98	1.17	0.36	0.89
1	2½	4	1.35	0.52	0.82	1.38	0.53	0.84	1.24	0.47	0.75
1	2½	5	1.19	0.46	0.91	1.21	0.46	0.92	1.10	0.42	0.83
1	2½	6	1.07	0.41	0.97	1.07	0.41	0.98	0.98	0.37	0.89
1	3	4	1.26	0.58	0.77	1.28	0.58	0.78	1.15	0.52	0.72
1	3	5	1.11	0.51	0.85	1.14	0.52	0.87	1.03	0.47	0.78
1	3	6	1.01	0.46	0.92	1.02	0.47	0.93	0.92	0.42	0.84
1	3	7	0.91	0.42	0.97	0.92	0.42	0.98	0.84	0.38	0.89
1	3½	5	1.05	0.56	0.80	1.07	0.57	0.82	0.96	0.50	0.76
1	3½	6	0.95	0.50	0.87	0.97	0.51	0.89	0.88	0.46	0.80
1	3½	7	0.87	0.47	0.93	0.89	0.47	0.95	0.80	0.43	0.85
1	3½	8	0.80	0.42	0.97	0.82	0.43	1.01	0.73	0.39	0.89
1	4	6	0.90	0.55	0.82	0.92	0.56	0.84	0.83	0.51	0.77
1	4	7	0.83	0.51	0.89	0.84	0.51	0.90	0.77	0.47	0.81
1	4	8	0.77	0.47	0.93	0.78	0.48	0.95	0.71	0.43	0.86
1	4	9	0.71	0.43	0.97	0.73	0.44	1.01	0.65	0.40	0.89

WOODEN COLUMNS.

Safe Loads, in Tons, for Square White Pine Wooden Columns.

Height in Feet.	Side of Square Column in Inches.								
	4"	6	8	10	12	14	16	18	20."
4'	6.4	17.8	35.0	57.2	84.6	117.0	154.6	196.8	244.2
6	4.4	14.3	30.2	51.6	78.7	110.0	147.3	189.3	237.2
8	3.0	11.1	25.4	45.7	71.4	102.8	140.0	181.7	229.0
10	2.2	8.6	21.1	39.7	64.3	94.9	130.5	171.4	218.4
12	1.6	6.8	17.5	34.2	57.1	86.0	121.0	161.3	207.2
14	1.2	5.4	14.5	29.4	50.5	77.6	111.2	150.1	194.9
16	1.0	4.4	12.2	25.3	44.5	70.0	101.6	139.2	182.6
18	.8	3.6	10.2	21.8	39.2	62.7	92.7	128.2	170.2
20	.6	3.0	8.7	18.9	34.6	56.3	84.3	118.2	158.5
22		2.6	7.5	16.5	30.7	51.0	76.7	108.6	147.3
24		2.2	6.5	14.5	27.2	45.6	69.7	100.0	136.6
26		1.9	5.6	12.8	24.3	41.4	63.3	91.8	126.8
28		1.6	5.0	11.3	21.8	37.2	57.7	84.6	117.6
30		1.5	4.4	10.1	19.6	33.9	52.9	77.8	108.9
32		1.3	3.9	9.0	17.6	30.5	48.4	71.7	101.1
34		1.1	3.5	8.2	16.0	27.7	44.5	66.4	93.8
36		1.0	3.2	7.4	14.5	25.5	40.9	61.3	87.4
38		.9	2.9	6.7	13.3	23.5	37.5	56.8	81.2
40		.8	2.6	6.1	12.2	21.6	34.7	52.6	75.6
42			2.4	5.6	11.2	19.9	32.2	49.0	70.8
44			2.2	5.1	10.3	18.5	30.0	45.6	66.1
46			2.0	4.7	9.5	17.1	27.7	42.6	61.9
48			1.8	4.4	8.8	16.0	25.8	39.8	58.0
50			1.7	4.2	8.2	14.8	24.1	37.2	54.3
52					7.6	14.0	22.7	34.7	51.0
54					7.1	13.2	21.3	32.8	48.2
56					6.6	12.3	19.9	30.8	45.4
58					6.2	11.5	18.8	28.8	42.8
60'					5.9	10.6	17.6	27.4	40.3

Note:—

Oak columns will carry loads 15 per. cent greater than given above.

Southern Yellow Pine will carry loads 40 per cent greater than given above.

The loads given in the table are for columns in permanent structures.

For columns in temporary structures add 25 per cent to the above loads.

WOODEN BEAMS.

Table of safe quiescent loads in pounds for horizontal rectangular beams of White Pine or Spruce, one inch broad, supported at both ends & uniformly distributed load.

Span in Feet	Depth of Beam in Inches.					
	6"	8	10	12	14	16"
5'	800	1420	2220	3200	4350	5690
6	670	1180	1850	2670	3630	4740
7	570	1010	1590	2280	3110	4060
8	500	890	1290	2000	2720	3560
9	440	790	1210	1780	2420	3160
10	400	710	1110	1600	2180	2840
11	360	650	1010	1450	1980	2590
12	330	590	930	1330	1810	2370
13	310	550	850	1230	1680	2190
14	290	510	790	1140	1560	2030
15	270	470	740	1070	1450	1900
16	250	440	690	1000	1360	1780
17	230	420	650	940	1280	1670
18	220	400	620	890	1210	1580
19	210	380	590	840	1150	1500
20	200	360	560	800	1090	1420
21	190	340	530	760	1040	1350
22	180	320	500	730	990	1290
23	170	300	480	700	950	1230
24	160	290	460	670	910	1180
25	160	280	440	640	870	1130
26	150	270	420	610	840	1090
27	150	260	400	590	810	1050
28	140	250	390	570	780	1010
29	140	250	380	550	750	980
30	130	240	370	530	730	950

This table has been calculated for extreme fibre stress of 1000 lbs. per square inch, being one-sixth the breaking stress, ordinary building timber of fair quality.

Oak and Yellow Pine will carry a load one-fourth greater.

When more accuracy is required, the weight of the beam itself must be deducted.

Care must be taken to let the beams rest for a sufficient distance on their supports to guard against crushing at the ends, especially in placing very heavy loads upon short but deep and strong beams.

LUMBER MEASURE.

Size.	Length in Feet.												
	6	8	10	12	14	16	18	20	22	24	26	28	30
1"x4"	2	2.7	3.3	4	4.7	5.3	6	6.7	7.3	8	8.7	9.3	10
1x6	3	4.0	5.0	6	7.0	8.0	9	10.0	11.0	12	13.0	14.0	15
1x8	4	5.3	6.7	8	9.3	10.7	12	13.3	14.7	16	17.3	18.7	20
1x10	5	6.7	8.3	10	11.7	13.3	15	16.7	18.3	20	21.7	23.3	25
1x12	6	8.0	10.0	12	14.0	16.0	18	20.0	22.0	24	26.0	28.0	30
2x4	4	5.3	6.7	8	9.3	10.7	12	13.3	14.7	16	17.3	18.7	20
2x6	6	8.0	10.0	12	14.0	16.0	18	20.0	22.0	24	26.0	28.0	30
2x8	8	10.7	13.3	16	18.7	21.3	24	26.7	29.3	32	34.7	37.3	40
2x10	10	13.3	16.7	20	23.3	26.7	30	33.3	36.7	40	43.3	46.7	50
2x12	12	16.0	20.0	24	28.0	32.0	36	40.0	44.0	48	52.0	56.0	60
4x4	8	10.7	13.3	16	18.7	21.3	24	26.7	29.3	32	34.7	37.3	40
4x6	12	16.0	20.0	24	28.0	32.0	36	40.0	44.0	48	52.0	56.0	60
4x8	16	21.3	26.7	32	37.3	42.7	48	53.3	58.7	64	69.3	74.7	80
4x10	20	26.7	33.3	40	46.7	53.3	60	66.7	73.3	80	86.7	93.3	100
4x12	24	32.0	40.0	48	56.0	64.0	72	80.0	88.0	96	104.0	112.0	120
6x6	18	24.0	30.0	36	42.0	48.0	54	60.0	66.0	72	78.0	84.0	90
6x8	24	32.0	40.0	48	56.0	64.0	72	80.0	88.0	96	104.0	112.0	120
6x10	30	40.0	50.0	60	70.0	80.0	90	100.0	110.0	120	130.0	140.0	150
6x12	36	48.0	60.0	72	84.0	96.0	108	120.0	132.0	144	156.0	168.0	180
8x8	32	42.7	53.3	64	74.7	85.3	96	106.7	117.3	128	138.7	149.3	160
10x10	50	66.7	83.3	100	116.7	133.3	150	166.7	183.3	200	216.7	233.3	250
12x12	72	96.0	120.0	144	168.0	192.0	216	240.0	264.0	288	312.0	336.0	360
12x14	84	112.0	140.0	168	196.0	224.0	252	280.0	308.0	336	364.0	392.0	420
14x14	98	130.7	163.3	196	228.7	261.3	294	326.7	359.3	392	424.7	457.3	490
16"x16"	128	170.7	213.3	256	298.7	341.3	384	426.7	469.3	512	554.7	597.3	640

Note- One Foot Board Measure = 12"x12"x1" = 144 cubic inches = $\frac{1}{2}$ cubic foot.

INDEX

PAGE.

Allowable stresses 7
Assumptions for calculations 9
Beams:
  Continuous 15
  Internal stress in 17
  Rectangular, derivation of formulae 10
  Tables of cubic feet of concrete of 97
  Tables of weight of concrete of 98
  Truss action in 19
  Wooden, tables of safe loads 101
Bending moments 15, 16, 30
Bond 8, 31
Bond:
  Formulae 32
  "Xpantrus" system 31
Calculations, general assumptions for 9
Chairs and spacers 5
Cheapness of installation 5
Columns 34
Columns:
  Hooped 35
  Unhooped 35
  Tables of cu. ft. of concrete 97
  Tables of weight of concrete for 98
  Wooden, tables of safe loads 100
Concrete:
  Floor slabs 30
  In beams and columns, tables 97
  Material required for one cu. yd. of rammed concrete tables 99
Continuous beams 15
Continuity of "Xpantrus" system 2, 4
Deformed bars 7
Design:
  Theory and methods 8, 45
  Notation of formulae, summary 39
  Formulae, summary 41
  Observations on 44
Diagonal tension (see shear)
Dimensions of "Xpantrus" bars 3, 52
Double reinforcement 33

PAGE.

Doubt, elimination of 3, 4
Economy of installation 5
  Of steel 3, 49
Efficiency of steel 3
Efficient shear members 2
Elastic limit 6
Elimination of doubt 3, 4
Engineering Department 45
Expanded:
  Heights of "Xpantrus" bar 3, 50, 53
  Proportion of length 26
Explanation of T-beam tables 54
Five bar unit frame, standard 37
Flange width, T-beams 28
Floor construction 47, 48
Floor slabs 30, 43, 48
Formulae:
  Bending moment 16
  Bond 32
  Derivation of, for rectangular beams 10
  Standard, notation for 39
  Summary of 41
  T-beams 29
General assumptions for calculations 9
Girders 27
Heights, expanded 3, 50, 53
Hooped columns 35
Installation, cheapness, accuracy and economy of 1, 4, 5
Inspection 1, 4
Inclined shear members 19
Internal stress in beams 17
Links and wedges 4, 6
Lumber measure 102
Manufacture, process of 3
Material for one cubic yard of rammed concrete, tables 99
Methods and theory of design 8, 45
Methods of reinforcing concrete 19, 20, 21
Notation for formulae 39
Observations on design 44
Order sheet 51
Practicability of "Xpantrus" System 1

PAGE.

Process of manufacture ... 3
Rectangular slabs approximating a square ... 31
Reinforced concrete, theory and methods of ... 8, 19
Reinforcement, transverse ... 30
Reinforcing steel specifications for ... 5
Rigidly connected shear members ... 2, 4, 19, 21
Rises, standard, of "Xpantrus" bars ... 53
Safe total loads for T-beams, tables:
  Simple beams ... 55
  Continuous beams ... 76
Safe loads for wooden beams, tables ... 101
Safe loads for wooden columns, tables ... 100
Sections of "Xpantrus" bars ... 52
Seven bar unit frame, standard ... 38
Shear and diagonal tension:
  Definition ... 17
  Inclined vs. vertical shear members ... 19
  Reinforcement calculation of ... 23
  Truss action in a concrete beam ... 18, 19
  "Xpantrus" shear members ... 19
Shear members:
  Calculation of ... 25
  Efficiency of ... 2
  Rigidity of ... 4, 19
Shipments ... 5
Sizes of "Xpantrus" bars ... 3, 52
Slabs:
  Bending moment ... 30
  Rectangular, approximating a square ... 31
  Transverse reinforcement ... 30
  "Xpantrus" bar applicable to ... 48, 30
Spacers and chairs ... 5
Special unit frame ... 36
Specifications for steel ... 5
Square slabs ... 31
Standard three bar unit frame ... 36
Standard five bar unit frame ... 37
Standard seven bar unit frame ... 38
Standard rises of "Xpantrus" bars ... 53
Standards, "Xpantrus" ... 50
Steel, economy and efficiency of ... 3, 49
Stock sizes of "Xpantrus" bars ... 53
Summary:
  Notation ... 39
  Formulae ... 41
Tables for:
  Cubic feet of concrete of rectangular beams and columns ... 97
  Lumber measure ... 102
  Material for one cubic yard of rammed concrete ... 99
  Safe total loads for T-beams:
    Simple beams ... 55
    Continuous beams ... 76

PAGE.

Tables for:
  Safe loads for wooden columns ... 100
  Safe loads for wooden beams ... 101
  Weight of concrete of rectangular beams and columns ... 98
T-beams:
  Explanation of tables for ... 54
  Formulae ... 29
  Safe total loads for:
    Simple beams ... 55
    Continuous beams ... 76
  Width of flange ... 28
Three bar unit frame, standard ... 36
Theory and methods of design ... 8, 45
Transverse reinforcement ... 30
Truss action in a concrete beam ... 19
Typical design, "Xpantrus" system ... 47
Unhooped columns ... 35
Unit frame:
  Five bar standard ... 37
  Seven bar standard ... 38
  Special ... 36
  Three bar standard ... 36
Unit shear ... 22
Vertical shear members ... 19
Wedges and links ... 4, 6
Width of flange, T-beams ... 28
"Xpantrus" bars:
  Applicable to slabs ... 30
  Calculation of shear members of ... 25
  Economy of steel of ... 3, 49
  Efficient shear members of ... 2
  Expanded heights ... 3, 50, 53
  Proportion of lengths expanded ... 26
  Process of manufacture ... 3
  Rigid shear members of ... 4, 19
  Sizes and dimensions ... 3, 52
  Standard rises of ... 53
  Stock sizes of ... 53
  Truss action of ... 18
  T-beams reinforced with ... 55, 76
"Xpantrus" bridge ... 48
"Xpantrus" standards ... 50
"Xpantrus" system:
  Bond ... 31
  Continuity, cheapness, accuracy of installation, efficiency of steel, elimination of doubt, inspection and practicability ... 1, 2, 3, 4
  Typical design ... 47
"Xpantrus" unit frames ... 36, 37, 38

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